RAILWAY SIGNALING

VOLUME I

WIRES AND CABLES—LINE CONSTRUCTION

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HIGHWAY CROSSING SIGNALS

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HIGHWAY CROSSING SIGNALS.

WIRES AND CABLES*

1. A **wire** is a body of metal of uniform cross-section, and generally of considerable length compared to its cross-section, which is produced by the process known as *wire-drawing.*

2. A **cable,** as the term is used in the following articles, consists of a number of wires collected together.

3. The metals and alloys of which wires and cables are made may be divided into two classes. One of these includes such metals and alloys as have a comparatively low specific resistance, which may be used to transmit electrical energy with comparatively little loss; while the other includes metals and alloys with a higher specific resistance, which may be used when it is desired to absorb electrical energy; that is, to convert it into heat.

METALS AND ALLOYS WITH A LOW SPECIFIC RESISTANCE

4. Metals in their pure state possess the highest conductivity and therefore make the best conductors. However, of the many metals capable of transmitting electrical energy with comparatively little loss, only *copper, aluminum* and *iron,* are commercially used in this condition, although most of the metals, and certain of the other elements, enter into the alloys which are used for various electrical purposes. *Platinum* and

*For the general properties of the materials mentioned in the following articles see **Chemistry, Materials** and **Magnetism and Electricity.**

mercury are used in the pure state to a limited degree as conductors, on account of special properties which they possess.

5. Copper: At the present time the metal copper is used to the greatest extent for electrical transmission purposes. This is due to the fact that it is not only one of the best conductors, but that it is also ductile, strong, and low priced. When all these qualities are averaged, no other metal is as good for service of this kind.

6. With the object of finding a material that would be superior to copper, many alloys of copper have been carefully tested. As a result it has been found that the effect of impurities, or alloying metals, is to decrease the conductivity, even a small percentage having a considerable effect. Some of the alloys are stronger than pure copper, but their conductivity is so much lower that they are inferior for electrical transmission purposes, when the increased weight of material required by their use is considered. In addition the strong alloys have the disadvantage of being generally more difficult to work than copper. Those alloys, whose conductivity approaches that of pure hard drawn copper, are always weaker than that metal.

7. The conductivity and strength of copper are dependent to a certain degree on the manner in which it is worked. Thus hard drawn wire has a lower conductivity than soft annealed wire, but a much greater tensile strength. The properties are also affected to some extent by the size of the wire, and flaws and other imperfections have a considerable effect.

TENSILE STRENGTH*

Hard-Drawn Copper Wire

Size of Wire B. & S. G.	Breaking Weight		Size of Wire B. & S. G.	Breaking Weight	
	Lbs.	Lbs. per sq. in.		Lbs.	Lbs. per sq. in.
1	3565	54200	8	788	60500
2	2892	55500	9	630	61100
3	2338	55600	10	506	61600
4	1890	57600	11	403	62000
5	1520	58500	12	318	62400
6	1221	59300	14	202	63100

8. **Aluminum**: Next to copper, aluminum is of importance as a conductor for electrical transmission. As in the case of copper, its conductivity and strength are considerably reduced by the presence of impurities, alloying metals, and by flaws and imperfections.

9. The conductivity of commercial aluminum wire is approximately 61% of that of hard drawn copper, so that, for equal conductivity, an aluminum wire with a cross-section about 64% greater than that of the copper would be required. The tensile strength of such an aluminum wire would only be about 63% of that of the equivalent copper wire, but due to the difference in the specific gravities of the metals, the aluminum wire would only weigh about half as much as the copper wire, thus being somewhat superior to copper as far as supporting its own weight is concerned. When aluminum wire can be purchased for twice the price of copper wire, the cost for equal length and conductivity is nearly the same.

10. For the same conductivity aluminum has the advantage over copper of being much lighter, somewhat stronger compared to its weight, and of exposing a larger radiating surface. Due to the increased size, however, it exposes more surface for the wind to act upon and to collect sleet, and can only be used

*From No. XVII Handbook, Standard Underground Cable Co., copyright 1906.

COPPER WIRE TABLE

Brown & Sharpe Gauge

B. & S. or A. W. G. No.	Diameter in Inches	Area in Circular Mils	Area in Square Mils	Pounds per 1,000 ft.	Feet per Pound	Ohms per 1,000 ft. at 20° C. or 68° F.	Feet per Ohm at 20° C. or 68° F.	Ohms per Pound at 20° C. or 68° F.	Pounds per Ohm at 20° C. or 68° F.
0000	0.460	211,600	166,190	640.5	1.561	.04893	20,440	.00007639	13,090
000	0.4096	167,800	131,790	508.0	1.969	.06170	16,210	.0001215	8,232
00	0.3648	133,100	104,518	402.8	2.482	.07780	12,850	.0001931	5,177
0	0.3249	105,500	82,887	319.5	3.130	.09811	10,190	.0003071	3,256
1	0.2893	83,690	65,732	253.3	3.947	.1237	8,083	.0004883	2,048
2	0.2576	66,370	52,128	200.9	4.977	.1560	6,410	.0007765	1,288
3	0.2294	52,630	41,339	159.3	6.276	.1967	5,084	.001235	810.0
4	0.2043	41,740	32,784	126.4	7.914	.2480	4,031	.001963	509.4
5	0.1819	33,100	25,999	100.2	9.980	.3128	3,197	.003122	320.4
6	0.1620	26,250	20,618	79.46	12.58	.3944	2,535	.004963	201.5
7	0.1443	20,820	16,351	63.02	15.87	.4973	2,011	.007892	126.7
8	0.1285	16,510	12,967	49.98	20.01	.6271	1,595	.01255	79.69
9	0.1144	13,090	10,283	39.63	25.23	.7908	1,265	.01995	50.12
10	0.1019	10,380	8,155	31.43	31.82	.9972	1,003	.03173	31.52
11	0.09074	8,234	6,467	24.93	40.12	1.257	795.3	.05045	19.82
12	0.08081	6,530	5,129	19.77	50.59	1.586	630.7	.08022	12.47
13	0.07196	5,178	4,067	15.68	63.79	1.999	500.1	.1276	7.840
14	0.06408	4,107	3,225	12.43	80.44	2.521	396.6	.2028	4.931
15	0.05707	3,257	2,558	9.858	101.4	3.179	314.5	.3225	3.101
16	0.05082	2,583	2,029	7.818	127.9	4.009	249.4	.5128	1.950

17	0.04526	2,048	1,609	6.200	161.3	5.055	197.8	.8153	1.226
18	0.04030	1,624	1,276	4.917	203.4	6.374	156.9	1.296	0.7713
19	0.03589	1,288	1,012	3.899	256.5	8.038	124.4	2.061	0.4851
20	0.03196	1,022	802	3.092	323.4	10.14	98.66	3.278	0.3051
21	0.02846	810.1	636.3	2.452	407.8	12.78	78.24	5.212	0.1919
22	0.02535	642.4	504.6	1.945	514.2	16.12	62.05	8.287	0.1207
23	0.02257	509.5	400.2	1.542	648.4	20.32	49.21	13.18	.07588
24	0.02010	404.0	317.3	1.223	817.6	25.63	39.02	20.95	.04773
25	0.01790	320.4	251.7	0.9699	1,031	32.31	30.95	33.32	.03002
26	0.01594	254.1	199.6	0.7692	1,300	40.75	24.54	52.97	.01888
27	0.0142	201.5	158.3	0.6100	1,639	51.38	19.46	84.23	.01187
28	0.01264	159.8	125.5	0.4837	2,067	64.79	15.43	133.9	.007466
29	0.01126	126.7	99.53	0.3836	2,607	81.70	12.24	213.0	.004696
30	0.01003	100.5	78.94	0.3042	3,287	103.0	9.707	338.6	.002953
31	0.008928	79.70	62.60	0.2413	4,145	129.9	7.698	538.4	.001857
32	0.007950	63.21	49.64	0.1913	5,227	163.8	6.105	856.2	.001168
33	0.007080	50.13	39.37	0.1517	6,591	206.6	4.841	1,361	.0007346
34	0.006305	39.75	31.22	0.1203	8,311	260.5	3.839	2,165	.0004620
35	0.005615	31.52	24.76	.09543	10,480	328.4	3.045	3,441	.0002905
36	0.0050	25.0	19.64	.07568	13,210	414.2	2.414	5,473	.0001827
37	0.004453	19.83	15.57	.06001	16,660	522.2	1.915	8,702	.0001149
38	0.003965	15.72	12.35	.04759	21,010	658.5	1.519	13,870	.00007210
39	0.003531	12.47	9.79	.03774	26,500	830.4	1.204	22,000	.00004545
40	0.003145	9.888	7.77	.02993	33,410	1,047.0	0.955	34,980	.00002858

This table is based on the following data: Specific gravity of copper = 8.89. Resistance in terms of the international ohm. Matthiessen's standard resistivity, one meter gram of soft drawn copper = 0.141729 international ohm at 0° C. Matthiessen's temperature coefficient = 1.07968.

to advantage where it does not require an insulating covering. On account of the liability of flaws, and the fact that the vibration caused by the wind tends to decrease the strength of large wires, aluminum should always be used stranded, even in the smaller sizes.

PROPERTIES OF COPPER AND ALUMINUM WIRE COMPARED*

	Hard-Drawn Copper	Soft-Drawn Copper	Aluminum
Conductivity referred to Mathiessen's Standard	96 to 99	99 to 102	61 to 63
Tensile strength at the elastic limit.** Lbs. per sq. in.	35,000 to 40,000	3,000 to 5,000	14,000
Tensile strength ultimate	45,000 to 68,000	25,000 to 45,000	20,000 to 35,000
Specific gravity	8.93	8.89	2.68
Lbs. per cu. in.	0.323	0.321	.097
Coef. of Exp.	.0000095	.0000095	.0000128

11. As aluminum wire is soft and therefore easily dented and abraded, considerable care is required in handling it. Joints are best made mechanically as the metal is difficult to solder. Aluminum is highly electropositive,† so that as far as possible it should not come into contact with other metals,

*From Del Mar's Electric Power Conductors.

**When various loads, increasing in amount, are placed on a wire it is stretched, the amount of stretch being proportional to the load up to a certain limit, called the *elastic limit*. Beyond this limit the rate of stretch, instead of being proportional to the load, increases, and if the load is removed the wire will not generally return to its original length, which it will usually do as long as the load is within the elastic limit.

†When two different metals come in contact with each other there is generated an E. M. F., the value of which depends on the kind of metal and other conditions. This E. M. F. tends to cause current to flow from one of the metals to the other, the first being said to be *electropositive* to the second, which is therefore electronegative to the first. Aluminum is probably electropositive in all cases of direct contact, and the value of the E. M. F. generated, tending to cause current to flow from it to any other metal, is greater than that which would be generated if another metal were substituted in its place. Hence it is said to be highly electropositive.

as electrolysis is liable to occur. Under ordinary conditions pure aluminum is not acted upon to any extent by the atmosphere, so that it may generally be considered permanent. However, its use is considered unsafe in vicinities where it is exposed to the fumes of chemical works, etc.

RESISTANCE OF ALUMINUM WIRE*

Conductivity 62 in the Matthiessen Standard Scale.

Pure aluminum weighs 167.111 pounds per cubic foot.

B. & S. or A. W. G. No.	Ohms per 1000 ft. at 70° F.	Feet per Ohm at 70° F.	Ohms per lb.
0000	.07904	12652.	.00040985
000	.09966	10034.	.00065102
00	.12569	7956.	.0010364
0	.15849	6310.	.0016479
1	.19982	5005.	.0026194
2	.25200	3968.	.0041656
3	.31778	3147.	.0066250
4	.40067	2496.	.010531
5	.50526	1975.	.016749
6	.63720	1569.	.026628
7	.80350	1245.	.042335
8	1.0131	987.0	.067318
9	1.2773	783.0	.10710
10	1.6111	620.8	.17028
11	2.0312	492.4	.27061
12	2.5615	390.5	.43040
13	3.2300	309.6	.68437
14	4.0724	245.6	1.0877
15	5.1354	194.8	1.7308
16	6.4755	154.4	2.7505
17	8.1670	122.5	4.3746
18	10.300	97.10	6.9590

12. Iron: This metal is used extensively as a conductor where the amounts of energy to be transmitted are small. It is seldom found commercially as pure as copper, it being difficult to obtain it free from alloying materials. The purest irons come from Norway, Sweden, and Russia, due to the

*The Aluminum Company of America.

character of the ore available at those places and to the method of working.

13. Pure iron wire has a specific resistance about *six* times greater than that of copper. In commercial wire this value is increased to about *seven and one-half* times that of copper. Steel has a greater tensile strength than iron, but the specific resistance, even in the softest qualities, is from *nine* to *twelve* times that of copper. Cast steel, the tensile strength of which is very high, may have a specific resistance as great as *sixteen* times that of copper, and consequently its use is limited to long spans where weaker materials would not serve.

14. Iron and steel wires must be protected from the atmosphere to prevent them from rusting. A coating of zinc has been found to give the best results for this purpose, and wires protected in this way are said to be *galvanized*.

GALVANIZED IRON WIRE*

B.W.G. No.	Diam. in Mils	Weight, Lbs. per 1,000 ft.	Breaking Weight, in lbs.		Resistance per Mile in Ohms		
			Iron	Steel	E. B. B.	B. B.	Steel
0	340	304	4821	9079	2.93	3.42	4.05
1	300	237	3753	7068	3.76	4.4	5.2
2	284	212	3363	6335	4.91	4.91	5.8
3	259	177	2796	5268	5.04	5.9	6.97
4	238	149	2361	4449	5.97	6.99	8.26
5	220	127	2019	3801	6.99	8.18	9.66
6	203	109	1719	3237	8.21	9.6	11.35
7	180	85	1350	2545	10.44	12.21	14.43
8	165	72	1134	2138	12.42	14.53	17.18
9	149	58	915	1720	15.44	18.06	21.35
10	134	47	750	1410	18.83	22.04	26.04
11	120	38	600	1131	23.48	27.48	32.47
12	109	31	495	933	28.46	33.3	39.36
13	95	24	375	709	37.47	43.85	51.82
14	83	18	288	541	49.08	57.44	67.88
15	72	13.7	216	407	65.23	76.33	90.21
16	65	11.1	177	332	80.03	93.66	110.7
17	58	8.9	141	264	100.5	120.4	139.
18	49	6.3	99	189	140.8	164.8	194.8

*Roebling.

15. The terms used in the preceding table for different grades of galvanized wire have the following meaning.

E. B. B., *Extra Best Best,* is made of the very best iron, as nearly pure as any commercial iron, being soft, tough, uniform, and of high conductivity.

B. B., *Best Best,* is of iron, showing in mechanical tests almost as good results as the E. B. B., but not quite as soft and being somewhat lower in conductivity.

The *Steel* wire is of greater strength, but lower conductivity. The breaking weights given for steel wire are not those of steel telegraph wire. They apply to wire with a tensile strength of 100,000 lbs. per sq. in. This strength is higher than that of telegraph wire. By taking 100,000 lbs. per sq. in. as the breaking strain of steel wire, the breaking strain of any other wire may easily be computed from the table. Thus for a wire of 80,000 lbs. per. sq. in. breaking strain, take eight-tenths of the tabulated breaking strain for that size of wire as given in the table.

16. Platinum: The use of this metal is limited commercially by its great cost. Its only extensive application at the present time is where conductors must pass through a glass wall, and form a gas tight joint with the glass. The specific resistance is about *six* times that of copper.

17. Mercury: Mercury is used to a limited degree in devices where a liquid conductor is required. The specific resistance of this metal is about *sixty* times that of copper.

18. Copper-Clad Steel Wire: In certain classes of work, such as in railway signal and telegraph lines, the size of the wire used is often determined by its strength rather than its conductivity. In such cases copper-clad steel wire, Fig. 1, may be used to advantage, the steel center providing a high tensile strength and elastic limit, while the copper jacket provides a comparatively high conductivity, and protects the steel from the action of the atmosphere.

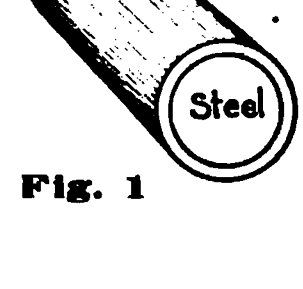


Fig. 1

19. Wire of this kind has an average conductivity equal to about 40% of that of the same size of hard-drawn copper wire, and weighs about 7% less than copper wire of the same size and length. Its tensile strength at the elastic limit varies with the size of the wire from about 70% to 150% greater than that of the same size copper wire, the smaller value being for No. 0000 B. & S. gauge wire and the larger value for No. 20. The breaking strength also varies with the size of the wire from about 14% to 65% greater than that of the same size copper wire. Thus where copper wire of more than the required conductivity must be used to obtain sufficient strength, a smaller copper-clad steel wire may often be substituted, and both a considerable saving in cost effected and a greater strength obtained.

COPPER AND COPPER-CLAD STEEL WIRE COMPARED*

B. & S. G. No.	Weight in lbs. per 1,000 ft.		Av. Resistance Ohms per 1,000 ft. at 60° F.		Approximate Elastic Limit		Approximate Breaking Weight	
	Copper-Clad	Copper	Copper-Clad	Copper	Copper-Clad	Copper	Copper-Clad	Copper
0000	594.5	639.8	.1202	.04906	8523.	4986.	9470.	8310.
000	471.4	507.3	.1516	.06189	6660.	3498.	7400.	6580.
00	373.9	402.4	.1912	.07803	5922.	3135.	6580.	5226.
0	296.6	319.2	.2408	.09831	4707.	2735.	5230.	4558.
1	235.1	253.0	.3040	.1241	4104.	2248.	4560.	3746.
2	186.4	200.6	.3835	.1565	3240.	1876.	3600.	3127.
3	147.8	159.1	.4832	.1972	2970.	1488.	3300.	2480.
4	117.3	126.2	.6095	.2488	2340.	1180.	2600.	1967.
5	92.92	100.0	.7688	.3138	1980.	936.	2200.	1559.
6	73.73	79.35	.9690	.3955	1530.	742.	1700.	1237.
7	58.50	62.96	1.221	.4986	1305.	588.	1450.	980.
8	46.39	49.92	1.540	.6288	1035.	467.	1150.	778.
9	36.77	39.57	1.944	.7934	855.	370.	950.	617.
10	29.17	31.39	2.449	.9996	684.	293.	760.	489.
11	23.11	24.87	3.092	1.262	558.	234.	620.	388.
12	18.34	19.74	3.898	1.591	441.	184.	490.	307.
13	14.56	15.67	4.908	2.003	351.	146.	390.	244.
14	11.54	12.42	6.190	2.527	288.	116.	320.	193.
15	9.160	9.858	7.802	3.185	225.	91.	250.	153.
16	7.250	7.802	9.855	4.022	180.	80.	200.	133.
17	5.765	6.204	12.39	5.059	149.	56.	165.	97.
18	4.562	4.910	15.66	6.392	117.	46.	130.	77.
19	3.621	3.897	19.74	8.057	90.	37.	100.	61.
20	2.877	3.096	24.83	10.14	72.	29.	80.	48.

*Duplex Metals Co.

WIRE GAUGES
In Decimal Parts of an Inch

Number of Wire Gauge	Brown & Sharpe B. & S. G.	Birmingham or Stubs B. W. G.	Roebling or Washburn & Moens.	English Legal Standard
6—0	.....	....	.460	.464
5—0	.....	....	.430	.432
4—0	.4600	.454	.393	.400
3—0	.4096	.425	.362	.372
2—0	.3648	.380	.331	.348
0	.3249	.340	.307	.324
1	.2893	.300	.283	.300
2	.2576	.284	.263	.276
3	.2294	.259	.244	.252
4	.2043	.238	.225	.232
5	.1819	.220	.207	.212
6	.1620	.203	.192	.192
7	.1443	.180	.177	.176
8	.1285	.165	.162	.160
9	.1144	.148	.148	.144
10	.1019	.134	.135	.128
11	.09074	.120	.120	.116
12	.08081	.109	.105	.104
13	.07196	.095	.092	.092
14	.06408	.083	.080	.080
15	.05706	.072	.072	.072
16	.05082	.065	.063	.064
17	.04525	.058	.054	.056
18	.04030	.049	.047	.048
19	.03589	.042	.041	.040
20	.03196	.035	.035	.036
21	.02846	.032	.032	.032
22	.02534	.028	.028	.028
23	.02257	.025	.025	.024
24	.02010	.022	.023	.022
25	.01790	.020	.020	.020
26	.01594	.018	.018	.018
27	.01419	.016	.017	.0164
28	.01264	.014	.016	.0148
29	.01125	.013	.015	.0136
30	.01002	.012	.014	.0124
31	.00893	.010	.0135	.0116
32	.00795	.009	.0130	.0108
33	.00708	.008	.0110	.0100
34	.00630	.007	.0100	.0092
35	.00561	.005	.0095	.0084
36	.00500	.004	.0090	.0076
37	.00445	....	.0085	.0068
38	.00397	....	.0080	.0060
39	.00353	....	.0075	.0052
40	.00314	....	.0070	.0048

METALS AND ALLOYS WITH A COMPARATIVELY HIGH SPECIFIC RESISTANCE

20. Metals and alloys belonging to this class are used principally for the purpose of absorbing electrical energy. Therefore the specific resistance must be comparatively high and the temperature coefficient generally small, so that the resistance will not change too much with the temperature.

21. Of the pure metals *iron* is the only one that is used to any extent for work of this kind and, on account of its large temperature coefficient, its use must be confined to purposes where the change in the value of its resistance does not matter. The use of the other pure metals with a sufficiently high specific resistance, such as *nickel* and *platinum*, is not practical on account of reasons such as the difficulty in working them, high cost, etc.

22. Many of the alloys possess a high specific resistance and a very small temperature coefficient, some of those having the highest specific resistance also having the lowest temperature coefficient. Those which are most used are *german-silver, platinoid, nickel-silver, nickel-copper,* and similiar alloys which are known by trade names. Other alloys, of which *manganine* is an example, are used principally for standard resistances, on account of their permanence and extremely low temperature coefficients.

RESISTANCE WIRES

ALLOY	Approx. Ohms per Mil-ft. at 70° F.	Approx. Temp. Coef. per deg. F.
Platinum Silver	191	.000135
Patent-Nickel	206	.000105
Platinoid	195	
18% German Silver	217	.00017
Driver-Harris Co.'s Manganine . . .	249	.00001
Baker & Co.'s Iala, hard	301	—.000006
" " " " soft	282	.000003
Krupp's metal	510	.000393
Driver-Harris Co.'s Manganin . . .	575	.00024
" " " "Climax" . . .	525	.0003
" " " "Advance" . . .	294	
" " " "L-T-E"	360	.00001
" " " "Monel". . . .	256	.0011
" " " "Ferro-Nickel" .	170	.00115

THE PROCESS OF MAKING WIRE

23. Iron or steel, which is ultimately to be drawn into wire, is first cast in the form of large ingots. These are then rolled and cut to size in the rolling-mill, forming what are termed *wire-bars,* measuring about 4 in. square and on the average about 3 ft. long. The material is sent in this form to the rod rolling-mill. Copper and bronze are cast directly into ingots of the required size for wire-bars, and are not subjected to any preliminary rolling or other operations, such as are performed on iron and steel.

24. In the rod rolling-mill the wire-bars are reduced to *wire-rods,* and thus prepared for the operations of wire-drawing. The first of the operations in the rod rolling-mill is to heat the wire-bars in reverberatory furnaces to the proper malleable temperature. This, in the case of iron and steel corresponds to the welding temperature, so that many of the flaws and imperfections are united and healed in the subsequent operations. After the bars have reached the proper temperature they are passed through a series of rolls, known as a wire-rod rolling train, which successively decrease the area of cross-section and increase the length. In addition the grooves in the rolls are so shaped that the metal is thoroughly forged. In this series of operations the wire-bar is reduced to a cylindrical rod in the neighborhood of ¼ in. in diameter, which is known as a *wire-rod.* This rod, which is of considerable length, is coiled on a drum and after removal from the drum is ready for the drawing operations.

25. Wire-rod from the rod rolling-mill is covered with a thick coating of scale, black oxide of iron or copper, which forms as a result of the heated rod being exposed to the air during the operations of rolling. The rod is also of uneven hardness or temper.

26. It is necessary, before the operations of wire-drawing are commenced, that the rod be uniformly soft and that the scale be removed. The first operation, therefore, previous to

drawing, is to anneal the rod. For this purpose the coils are placed in iron pots, heated to a dull red, and allowed to cool slowly. Following this the rod is cleaned or pickled to remove the scale. This is done in a hot bath of water and sulphuric acid, containing 10% of acid. When the scale is removed the rod is taken from the pickling bath and washed with water. Copper rod requires no further treatment as the air has comparatively little action on it. Iron and steel rods, however, require a protective coating to keep them from rusting. They are therefore placed in a bath of lime water which neutralizes the last traces of acid and prevents further oxidation.

27. Although copper is not affected by the pickling, iron and steel are rendered brittle, which is explained as due to the absorption of hydrogen during the process. They are restored to their former condition, however, by a baking process at a temperature of 250 deg. F.

28. After having passed through the foregoing processes the wire-bars are ready for the operations of wire-drawing, which consists in pulling the wire through a *drawplate.*

29. For the larger sizes of wire the drawplate is a block of chilled iron from $1\frac{1}{2}$ to 2 in. thick. This is provided with a number of holes which are shaped as shown in the section Fig. 2. The holes are graded in size from slightly smaller than the wire-rod to the size of the smallest wire that can be economically drawn through a plate of this kind; i.e., about $\frac{1}{16}$ in. in diameter. For the smaller sizes of wire the drawplate is made of steel instead of chilled iron

Fig. 2

30. In the process of drawing the wire is pulled through the different holes, starting with the largest one and each time taking the next smaller size. The power required is furnished by means of a horizontal revolving drum, on which the wire winds after it has passed through the drawplate.

31. A lubricant is applied to the wire just before it passes through the drawplate, to reduce the friction and the rate at which the plate wears out. For this purpose different materials are used for different kinds and sizes of wire. Thus dry flour is found to be the best lubricant for heavy, iron, lime-coated wire, while soft petroleum grease and soft soap are used for copper wires.

32. For producing the smaller sizes of wire, wire-drawing machines are used. These pull the wire through several drawplates successively, drums being provided between the plates to furnish the power.

33. The process of drawing metal into wire has a considerable effect on the physical characteristics of the metal, the outer surface seeming to be formed into a sort of skin and the metal to be strengthened. Thus copper bars having a tensile strength of 30,000 to 40,000 lbs. per sq. in., when drawn into wire show a strength of from 50,000 to 60,000 lbs. per sq. in.

GALVANIZING

34. Copper wire, when it is to be simply exposed to the ordinary action of the atmosphere and is not provided with an insulating covering, needs no protection, as the moisture and air have practically no action upon it. Iron and steel wire, however, must be protected from moisture and air, and the most efficient coating that has yet been used is a layer of zinc. The process of applying the zinc is termed *galvanizing,* and wire protected in this way is known as *galvanized wire.* Galvanizing is performed by the hot process as follows:

35. In order that the zinc may adhere firmly it is necessary that the surface of the iron or steel be free from scale. Therefore hard drawn wires, as they come from the drawplate, are ready for the process, since they are clean and bright. Annealed wires, however, must go through a cleaning process before they can be galvanized.

36. The process of galvanizing consists in passing the wires first through a bath of flux, consisting of a solution of chloride of zinc which contains a small percentage of pure hydro-chloric acid, and then through a bath of molten zinc. As the wires leave the zinc bath they pass through a bank of sand which removes the larger drops. After this they pass through the air until cooled sufficiently to be wound onto drums.

37. Wire galvanized in this way is known as galvanized wire, and is suitable for short telegraph lines, supporting wires, guy wires, etc. The weight of the zinc coating is from 5% to 7% of the original weight of the wire. As the wire to be galvanized is customarily drawn slightly smaller than standard size, the finished wire differs very little in diameter and weight from bare iron or steel wire of the same gauge number.

38. The term *double galvanized wire* is applied to such wire as has been given a coat of pure zinc as heavy as it possible to make it, thus producing a wire having a maximum life when exposed to the elements. The thickness of zinc is not absolutely uniform, varying from .003 in. to .005 in. in total thickness, one half of this being on each side of the wire.

39. Wire that is to be subjected to any weaving process requires a more flexible and consequently thinner coating of zinc. Therefore as it leaves the tank of molten zinc it is passed between asbestos wipers, which remove as much of the metal as possible, after which it is immediately cooled in a tank of water. The surface of wire treated in this way is as smooth as before galvanizing, but the coating, the weight of which is only about 2% of the original weight of the wire, affords only a slight protection. Consequently such wire is not suitable to be exposed to the action of air and moisture.

40. The standard test to determine the quality of the zinc coating is made as follows:

The wire is immersed for one minute in a saturated solution of sulphate of copper and then removed and wiped dry, this operation being repeated four times. If the coating is of suf-

ficient thickness and uniformity, no change will be noticed other than a slight blackening of the surface of the zinc. If the coating is thin or defective, copper is immediately deposited upon the exposed iron, as is made evident by the red color which appears. Excessive thickness may be detected by the breaks in the zinc coating when the wire is wound around its own diameter.

TINNING

41. Copper wire that is to be provided with a vulcanized rubber insulating covering is generally tinned to prevent the sulphur in the rubber from acting upon the metal. The process of tinning copper wire is similar to that of galvanizing iron and steel wire. The first step is to thoroughly clean all oxides and foreign matter from the surface of the wire, after which it is carried through one or two baths of tin maintained just above its melting point. This low temperature is necessary in order to avoid annealing the wire when it is hard-drawn. The thickness of coating is determined by the length of time during which the wire remains in the bath, and whether or not it is wiped upon leaving the bath. The surface of the molten tin is usually protected from oxidation by a layer of palm oil or low melting paint flux. When a very heavy coat of tin is desired the wire is frequently drawn from the bath without wiping and raised for a short distance perpendicularly in order to allow the surplus tin to drain off.

The important qualities of the completed wire are that the coat shall thoroughly cover every portion and be as heavily applied as is consistent with securing a smooth, uniform surface.

CABLES

42. When the diameter of a solid copper wire exceeds 0.46 in., or No. 0000 B. & S. gauge, it is only practical to make it in comparatively short lengths; i. e., less than about 300 ft., the length decreasing as the diameter is increased. On account

of this fact many joints would be required in a line using large size solid wires as conductors, which would add considerably to the expense of installation. In addition large solid wire is difficult to handle, and to straighten after it is once bent.

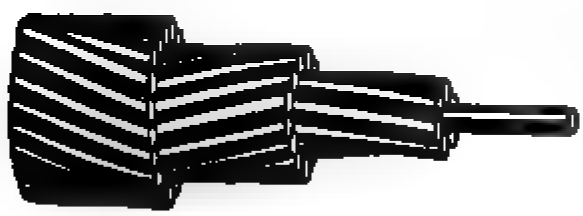


Fig. 3

43. To overcome these difficulties large conductors are generally built up in the form of cables from smaller wires. The type of cable which is in general use is called a **strand or concentric strand,** Fig. 3. It consists of a central core of either one straight wire, or two, three, or four wires twisted together,* around which are placed one or more layers of wires twisted spirally, each layer being twisted in the opposite direction to the layer directly beneath it. For great flexibility either a great number of small wires may be used, or a number of strands may be twisted together to form a rope, Fig. 4. Cables made by the latter method are said to be *rope-laid.*

Fig. 4

44. The diameter of a strand or cable may be computed by using the formula

$$D = d\,(1 + 2n),$$

in which d represents the diameter of each wire or strand and n the number of layers, not counting the core.

The area of a finished strand or cable is equal to the area of cross-section of one of the wires, multiplied by the number of wires in the strand or cable.

*Generally one wire is employed.

WIRES IN CONCENTRIC STRANDS

Number of Layer over Core	Core of One Wire		Core of Two Wires		Core of Three Wires		Core of Four Wires	
	Wires per Layer	Total Wires	Wires per Layer	Total Wires	Wires per Layer	Total Wires	Wires per Layer	Total Wires
1st	6	7	8	10	9	12	10	14
2nd	12	19	14	24	15	27	16	30
3rd	18	37	20	44	21	48	22	52
4th	24	61	26	70	27	75	28	80
5th	30	91	32	102	33	108	34	114
6th	36	127	38	140	39	147	40	154

Cables having more than one wire in the core are seldom used.

WIRES IN ROPE-LAID CABLES

Number of Layers over Core	Total Number of Strands	Total Number of Wires		
		7 Wires per Strand	19 Wires per Strand	37 Wires per Strand
1	7	49	133	259
2	19	133	361	703
3	37	259	703	1369
4	61	427	1159	2257
5	91	637	1729	3367
6	127	889	2413	4699

DIMENSIONS AND WEIGHTS OF STRANDS AND CABLES*

Copper and Aluminum

Size B. & S. G. and C. M.	Number of Wires in Strand	Diameter of Individual Wires in Inches	Diameter of Bare Cables in Inches	Approx. Weight of Copper per 1,000 ft. in lbs.	Approx. Weight of Aluminum per 1,000 ft. in lbs.
B. & S. G.					
14	7	0.0243	0.0729	13	3.87
12	7	0.0306	0.0918	20	5.95
10	7	0.0386	0.1158	32	9.54
8	7	0.0485	0.1455	51	15.2
6	7	0.0613	0.1839	81	24.1
5	7	0.0688	0.2064	101	30.2
4	7	0.0773	0.2319	128	38.5
3	7	0.0867	0.2604	161	48.5
2	7	0.0974	0.2922	203	61
1	19	0.0664	0.3320	256	77
0	19	0.0745	0.3750	323	97
00	19	0.0837	0.4190	408	123
000	19	0.094	0.4700	514	155
0000	19	0.1055	0.5280	647	195
250,000	37	0.0822	0.5754	765	239
300,000	37	0.0906	0.6342	919	276
350,000	37	0.0974	0.6818	1070	322
400,000	37	0.104	0.7280	1220	368
450,000	37	0.111	0.7770	1380	414
500,000	61	0.0906	0.8154	1530	460
550,000	61	0.095	0.8550	1680	506
600,000	61	0.0992	0.8928	1840	552
650,000	61	0.1033	0.9297	1990	597
700,000	61	0.1072	0.9648	2140	643
750,000	61	0.1109	0.9990	2300	690
800,000	61	0.1146	1.031	2450	735
900,000	61	0.1216	1.094	2750	834
1,000,000	61	0.1281	1.153	3060	920
1,000,000	91	0.1048	1.153	3030	924
1,250,000	91	0.1173	1.290	3830	1150
1,500,000	91	0.1284	1.412	4590	1380
1,750,000	127	0.1174	1.526	5360	1610
2,000,000	127	0.1255	1.631	6120	1840
2,000,000**	133	0.1226	1.84	6220	1850

*Del Mar's *Electric Power Conductors*.
**Rope-laid.

WEIGHTS AND RESISTANCES OF STRANDS

Size B. & S. G. and C. M.	Diam. Mils	COPPER Weight Lbs. per 1,000 ft.	COPPER Feet per Pound.	COPPER Ohms per 1,000 ft. at 68° F.	ALUMINUM Pounds per 1,000 ft.	ALUMINUM Feet per Pound	ALUMINUM Ohms per 1,000 ft.
1,000,000	1152	3050	.328	.010353	920	1.087	.01695
950,000	1125	2898	.345	.010900	874	1.144	.01784
900,000	1092	2745	.364	.01150	828	1.208	.01883
850,000	1062	2593	.385	.01218	782	1.279	.01994
800,000	1035	2440	.409	.01294	736	1.359	.02119
750,000	999	2288	.437	.01380	690	1.449	.02260
700,000	963	2135	.468	.01479	644	1.553	.02421
650,000	927	1983	.504	.01593	598	1.672	.02608
600,000	891	1830	.546	.01725	552	1.812	.02825
550,000	855	1678	.596	.01882	506	1.977	.03082
500,000	819	1525	.655	.02070	460	2.041	.03300
450,000	770	1373	.728	.02300	414	2.415	.03766
400,000	728	1220	.819	.02588	368	2.718	.04237
350,000	679	1068	.936	.02958	322	3.106	.04843
300,000	630	915	1.093	.03451	276	3.623	.05652
250,000	590	762	1.312	.04141	230	4.348	.06780
0000	530	645	1.550	.04893	194.7	5.733	.08010
000	470	513	1.949	.06170	154.4	6.477	.10100
00	420	406	2.463	.07780	122.4	8.165	.12740
0	375	322	3.106	.09811	97.1	10.300	.16050
1	330	255	3.941	.12370	77.0	12.990	.20250
2	291	203	4.926	.15600	61.0	16.400	.25540
3	261	160	6.250	.19670	48.5	20.620	.32200
4	231	127	7.874	.2480	38.5	25.970	.40600

NOTE—This table is calculated for untwisted strands; if the strand is twisted the cross-section of the copper at right angles to the length of the strand, the weight per unit length, and the resistance per unit length will each increase from 1% to 3%, and the length per unit weight will decrease from 1% to 3%, depending on the number of twists per unit length and the number of wires in the strand.

45. Flexible or Stranded Wire: Small wires which must be very flexible, for example the wire in ordinary lamp cord, are composed of a number of fine wires. These are often merely laid or bunched together, but frequently they are twisted so as to form a strand.

Flexible wires are usually built up of wires of such a size that the cross-section of their metal is the same as the cross-section of a solid wire having the same gauge number.

INSULATION

46. Conductors used for transmitting electrical energy must generally be insulated from each other and from the earth in some manner, with the following exceptions. For very low voltages, i. e., up to 15 volts, it is generally sufficient, even for interior work, to use bare wires supported on blocks or knobs of insulating material, provided proper precautions are taken to prevent accidental short-circuits. Bare wire may be used on out door pole lines, reliance being placed on the insulating supports and the air to prevent leakage. This is not true, of course, for closely settled districts and where there are many wires, an insulating covering being required under such conditions, for public safety and to prevent crosses and short-circuits.

47. Magnet Wire: The simplest form of insulating covering, which is generally used on wire employed in the construction of magnetic devices, is applied by winding the wire with one or more layers of cotton or silk yarn.* The yarn serves as a means of keeping the wires uniformly separated from each other, or from other parts, the insulation being obtained by reason of the insulating properties of the yarn itself when dry, and of the air contained in the pores of the covering.

48. The yarn used for this purpose is fine and uniform in size, but is rather loosely twisted, allowing it to cover the wire more effectively. It is wound on the wire by machines, which apply it uniformly both as to tension and pitch. When a greater thickness of insulation, than that afforded by one layer, is desired, or for the purpose of securing a more continuous or stronger covering, two or more layers of yarn, wound to form opposite spirals, are used. When a single layer is employed the wire is said to be **single covered,** and when two layers are used, **double covered.**

49. For a great many purposes magnet wire is satisfactorily insulated and needs no other treatment. Where the difference

*See **Magnetism and Electricity.**

of potential between adjacent wires is considerable, however, or for mechanical reasons, it is generally considered necessary to saturate the covering with an insulating material, such as shellac or asphaltum varnish, or to impregnate it with an insulating compound. The purpose of the extra insulating material is to prevent the yarn from absorbing moisture, and its value depends upon its ability to accomplish this result.

50. In some cases the insulating covering of magnet wire may be required to stand considerable heat, such as might result from the larger current caused to flow by a short-circuit. Under such conditions silk and cotton would char, becoming useless for insulating purposes. Asbestos, however, may be subjected to comparatively high temperatures without injuring its insulating properties, and hence is valuable in such cases. One method of insulating magnet wire with asbestos is to first wrap the wire with asbestos tape, over which is placed one or more windings of cotton yarn. Another method is to cover the wire with asbestos and saturate the asbestos with a compound, to prevent it from absorbing moisture and aid in holding it in place.

51. Magnet wire is used principally in the construction of coils for instruments used in signaling, telephoning, telegraphing, etc., and in the construction of coils for electrical machinery.

52. *Enameled Wire.** Cotton, silk, or asbestos insulation on magnet wire occupies considerable space compared to that required by the wire itself, particularly in the finer sizes.

A form of insulated magnet wire, known as *enameled wire,* has been developed, in which the conductor is coated with an elastic insulating enamel.

On account of the insulating qualities of the enamel, only a fraction of the thickness required for cotton or silk is needed, so that for a given number of turns the dimensions and weight of a coil are reduced, the saving being considerable when wires of the finer sizes are employed. This is shown by the following table.

*Information by the Western Electric and General Electric Companies.

WESTERN ELECTRIC BLACK ENAMEL WIRE COMPARED WITH SILK AND COTTON INSULATED WIRES

B. & S. G. No.	Approximate Feet per lb.			Approximate Turns per sq. in.		
	Single Silk	Single Cotton*	Enamel	Single Silk	Single Cotton*	Enamel
24	799	763	810	2142	1586	2162
25	1010	953	1019	2550	1810	2750
26	1263	1201	1286	3086	2356	3460
27	1584	1500	1620	4004	2954	4270
28	1988	1860	2042	4626	3340	5406
29	2405	2370	2570	5568	3508	6608
30	3148	2860	3240	7060	4626	8264
31	3933	3482	4082	8416	5240	10832
32	4913	4234	5132	10000	5482	13428
33	6129	5141	6445	12624	6400	16832
34	7646	6317	8093	13060	7440	21002
35	9536	7755	10197	18460	9420	26014
36	11889	9511	12813	20234	9802	31822
37	14577	11495	16110	23756	11580	43402
38	17648	13446	20274	27320	12280	54082
39	21465	15635	25519	33056	13840	69390
40	26558	18376	32107	38446	14520	86504

53. The enamel is not affected to any degree by moisture in the atmosphere, being superior to unimpregnated cotton, silk, or asbestos in this respect. In addition it will stand higher temperatures than either cotton or silk, although much inferior in this respect to asbestos. On account of the thinness of enamel insulation and its good heat conductivity, coils made of this wire run at a lower temperature than coils of cotton covered wire under the same conditions. The insulation on enameled wire is said to be tough enough to satisfactorily withstand the handling and abrasion, incident to the manufacture of insulated wire into apparatus. The wire is not injured by clean mineral oil, but turpentine, alcohol, animal and vegetable oils, and similar substances must not be allowed to come into contact with it.

54. Annunciator wire, which is used for wiring electric

*No. 100 Cotton.

bells, annunciators, etc., consists of copper wire wound with cotton yarn in a manner similar to that in which magnet wire is wound, the winding, however, being saturated with paraffine or some special insulating compound. It is generally double wound with heavy yarn, and the last covering finished so that the wire presents a smooth even appearance.

55. **Office wire,** which is used for interior work, such as telephone and telegraph wiring, and quite extensively for connecting other electrical instruments, is similar to annunciator wire. The covering, however, consists either of two braids of cotton yarn, or one winding over which is placed a braid, the whole being saturated with paraffine or other suitable insulating material.

56. On account of the fact that paraffine absorbs and retains water, insulating coverings in which it is used are suitable only for dry places, and even then cannot be relied upon to maintain a high degree of insulation.

57. **Slow-burning Wire:** The insulation of this wire, Fig. 5, generally consists of a braided covering of cotton yarn in one

Fig. 5

or more layers, the covering being saturated with a fireproofing compound, whose solid constituent is not susceptible to moisture, and which will not burn even when ground in an oxidizable oil, such as linseed oil. The outside of the covering is finished smooth and hard. As the compound does not completely saturate the braid, the insulating qualities of the covering are diminished by moisture, and it is incapable of withstanding the effects of the elements. It is useful in hot, dry places where other forms of insulation would deteriorate rapidly, and also where wires are bunched, as on the back of a large switchboard, in which place the accumulation of rubber or weatherproof insulations might result in an objectionably large mass of highly inflammable material.

58. Weatherproof Wire: Asphaltum, particularly when compounded with some of the softer waxes, such as ozocerite, and applied in a molten condition, is capable of saturating the braided cotton covering placed over a conductor much more completely than the fireproofing compound used in slow-burning wire. In addition the material itself is not greatly affected by continuous exposure to moisture.

59. Insulation of this class, Fig. 6, is placed on a wire by first passing the wire through a bath of molten compound and

Fig. 6

then immediately braiding upon its surface one or more braids. After these have been saturated in the bath of molten compound, care being taken to thoroughly dry the braid previously, the insulated conductor is passed through a machine which rubs the compound into all the crevices and forms a continuous, smoothly polished surface. This smooth surface tends to prevent an accumulation of dirt, sleet, and snow when the wire is exposed to these conditions. By varying the method, so that each braid is saturated separately, and the conductor passed through the bath of compound between each braiding operation, a better grade of covering is produced. This is due to the fact that the finished covering depends for its insulation on the compound rather than upon the braid, which is intended merely to furnish a mechanical support for the compound.

60. Wire insulated in this manner is intended for outdoor use where moisture is certain and fireproof qualities are not necessary. It is also used to some extent for interior wiring.

WEATHERPROOF LINE AND HOUSE WIRE*
Solid Conductor

B. & S. Gauge	Double Covered			Triple Covered		
	Lbs. per Mile	Lbs. per 1,000 ft.	Diam. in Mils.	Lbs. per Mile	Lbs. per 1,000 ft.	Diam. in Mils.
0000	3690	699	725	3910	741	780
000	2970	562	655	3160	598	700
00	2390	452	588	2560	485	635
0	[illegible]	352	545	2020	382	590
1	1500	284	505	1650	312	550
2	1225	232	470	1340	254	515
3	980	186	385	1050	199	450
4	800	151	360	860	163	430
5	640	121	335	700	132	400
6	520	98	300	575	109	360
7	420	79	270	465	88	335
8	345	65	245	390	74	265
9	275	52	225	320	60	255
10	236	45	195	265	50	220
11	190	36	180	225	42	205
12	145	27	165	180	34	185
14	105	20	140	130	24	160
16	80	15	130	100	19	150
18	55	10	125	80	15	145
20	42	8	122	68	12	135

61. Slow-burning Weatherproof Wire: The insulation of wire of this class, Fig. 7, consists of a layer of the slow-burning

Fig. 7

*Standard Underground Cable Co.

insulation placed either over or under a layer of the weatherproof insulation, the outside of the wire being finished smooth.

The insulation of this wire does not burn as easily as the weatherproof insulation and it does not soften as readily when heated. It is not suitable for outside work.

62. Rubber Covered Wire: The insulation of this wire is one of the most important on account of the fact that it is practically not affected by moisture. It generally consists of

Fig. 8

a layer of some rubber compound. Fig. 8, protected by a braid of cotton yarn, which is saturated with a preservative compound similar to that used for weatherproof wire.

63. Rubber in its crude form is obtained from various plants that grow in the warmer countries, such as Brazil, Peru, etc. It is collected by making incisions in the rubber producing plants, and coagulating the juice obtained in this manner by any one of several methods. Thus the rubber that comes from Brazil is coagulated by means of the hot smoke produced by burning oily nuts, while that from Peru is coagulated by means of an acid plant juice.

64. Crude rubber is of various qualities, on account of differences in the plants producing it and also in the methods of gathering and coagulating the juice. The variation in the quality is due to varying proportions of the two constituents that go to make up crude rubber. One of these is a dry, fibrous, elastic material, not readily soluble in benzole, while the other is a sticky, semi-fluid substance, that is readily soluble in that

solvent. The better grades of rubber are those which contain the largest amount of the dry, fibrous, substance. Thus that grade of rubber, known by the name Para, which comes from Brazil and is coagulated by the hot smoke method, is superior to the other grades of rubber, as it contains the largest amount of this material.

65. Crude rubber is formed into various shapes by the natives who collect it and is received in these shapes by the manufacturer. It contains a considerable amount of impurities and differs from the pure gum, which is both white and odorless, due to the odor and color given it by the method of coagulation.

66. The first step in the process of manufacture consists in cutting the gum into pieces under warm water and removing the larger masses of foreign matter. The gum is then masticated under a stream of warm water by a pair of corrugated rollers, this operation removing most of the impurities, and dissolving and washing away the resin which has formed by a partial oxidation of the gum. Due to the removal of foreign matter, the gum during this process loses from 10% to as much at 50% of its weight, and at the same time absorbs considerable water.

67. After the gum has been thoroughly washed, it is taken from the masticating rolls in the form of sheets and hung in dark lofts for as long a period as possible. This is for the purpose of drying out the water absorbed during the washing process.

When dry the sheets are readily consolidated into large solid blocks by the application of pressure, and pure rubber sheet is cut from these blocks under water by rapidly moving knives. The pure gum is very adherent, freshly cut surfaces when brought into contact uniting so that they can not be again separated. It is also very absorbent, the dry gum being capable of taking up from 10% to 20% of pure water on continued immersion. Light and heat cause pure rubber to oxidize rapidly, it finally becoming a brittle resin. Pure rubber also softens at a slightly elevated temperature.

68. For these reasons rubber is little used in its pure state, but is generally mixed with other materials and submitted to a process known as *vulcanization.* This consists in mixing the dry gum with a certain quantity of sulphur, the quantity varying from 3% to 20%, the hardness of the finished product being partly dependent on the amount of sulphur used. The mixing is done by passing the ingredients many times through smooth hot rolls called grinders, until the mixture becomes uniform.

69. The final step of the process, after the mixture has been moulded into the desired form, consists in heating it for a certain time, the temperature being maintained at a definite point, the hardness of the product depending on the time and temperature, as well as on the percentage of sulphur. During the process the mixture undergoes a change, at first swelling and tending to become porous, but finally assuming a permanent character which is much superior to that of the pure gum.

70. In this condition the rubber is fairly stable, but under ordinary conditions it slowly deteriorates with age, finally becoming oxidized and brittle. An improvement is obtained in this respect by adding to the unvulcanized mixture substances, such as ground mica, chalk, etc., and oxides of lead, zinc, and other metals. Also the addition of certain resins improves the quality of the rubber. The compositions of compounds made in this way have usually been determined as a result of extensive experimental work and are generally kept secret. Some of them are known by such trade names as Kerite, Okonite, etc.

71. Copper wire, that is covered with vulcanized rubber, must be protected in some way from the action of the sulphur in the compound. As mentioned in Art. 41 this is generally accomplished by tinning the wire. However in some cases the copper is protected by one or two layers of compound containing no sulphur, which in turn is enclosed in a vulcanized sheath. Light stranded wires are protected by wrapping them with a tight close wind of cotton yarn.

72. Previous to being submitted to the vulcanizing process, rubber compounds are comparatively inelastic, very plastic, and clean surfaces are readily united by pressure. On account of these characteristics insulating coverings of rubber are applied to wires by two general methods. One of these makes use of the adhesive property of the unvulcanized compound. The rubber compound is first passed though calender rolls and formed into a thin sheet. This is cut into strips of the proper width to slightly more than half surround the wire to be insulated. A pair of these strips are then placed, one on each side of the wire, and rolled into close contact with it and the edges rolled together by a set of grooved wheels, the excess of rubber being trimmed off by a set of cutting wheels. This method is used for covering the larger sizes of wire, since the wire is easily kept in the center, insuring a uniform thickness of insulation on all sides. Sometimes several layers, placed so that the seams do not register, are used instead of one layer.

73. The smaller sizes of wire are covered by a machine* which forms the plastic rubber into a seamless tube surrounding the conductor. In this case the compound must be worked at a higher temperature than in the preceding case, in order that it may be plastic enough to be forced through the machine. In some cases, instead of one thick layer, a series of thin layers are placed on the wire by this process, thus insuring a more uniform thickness of insulation.

74. After the application of the compound and before it can be vulcanized, it must be surrounded by some material or fabric to prevent it from swelling and becoming porous during vulcanization. This is accomplished for the smaller wires by coiling them in a pan and packing powdered chalk or similar material closely around them. For the larger sizes, however, it is necessary to apply a braid or a covering of tape, or use some equivalent means.

75. The process of vulcanization consists in heating the wire and its covering to a temperature between 250 deg. and

*Called a spewing machine.

300 deg. F., for from half an hour to five or six hours, as determined by the quantity of sulphur in the compound and the hardness and elasticity required. For ordinary wires one hour at 265 deg. F. may be considered as the average practice.

In some cases the heating is done in dry air warmed by steam coils, and in other cases by direct exposure to dry steam, the latter method tending to produce better results.

76. The rubber covering deteriorates less rapidly when it is protected from the action of light and the elements. Therefore it is generally covered with a braid saturated with an asphlatum compound, the outer surface being finished smooth.

RUBBER COVERED WIRE*
Solid Conductor
National Electric Code

B. & S. Gauge	Diam. Single Braid, Inches	Weight per 1,000 ft., Pounds.		Weight per 1,000 ft. Leaded	Diam. Leaded** Inches	Thickness of Lead, Inches	Thickness of Rubber, Inches
		Single Braid	Double Braid				
18	.159	20	33	170	.253	$\frac{3}{64}$	$\frac{3}{64}$
16	.190	25	40	203	.284	$\frac{3}{64}$	$\frac{3}{64}$
14	.203	33	47	220	.297	$\frac{3}{64}$	$\frac{3}{64}$
12	.220	43	58	243	.314	$\frac{3}{64}$	$\frac{3}{64}$
10	.241	58	74	273	.335	$\frac{3}{64}$	$\frac{3}{64}$
8	.268	81	99	316	.362	$\frac{3}{64}$	$\frac{3}{64}$
6	.352	130	150	389	.411	$\frac{3}{64}$	$\frac{1}{16}$
5	.372	159	180	433	.431	$\frac{3}{64}$	$\frac{1}{16}$
4	.394	187	210	476	.453	$\frac{3}{64}$	$\frac{1}{16}$
3	.419	230	254	538	.478	$\frac{3}{64}$	$\frac{1}{16}$
2	.448	273	298	599	.507	$\frac{3}{64}$	$\frac{1}{16}$
1	.540	362	390	722	.570	$\frac{3}{64}$	$\frac{5}{64}$
0	.576	438	467	981	.636	$\frac{1}{16}$	$\frac{5}{64}$
00	.616	533	562	1116	.675	$\frac{1}{16}$	$\frac{5}{64}$
000	.661	648	678	1279	.721	$\frac{1}{16}$	$\frac{5}{64}$
0000	711	794	827	1473	.771	$\frac{1}{16}$	$\frac{5}{64}$

NOTE—Wire and Cable No. 1 B. & S. and larger have tape over rubber in addition to braid. Add $\frac{1}{16}$" to single braid for diameter of double braid.

*General Electric Co.
**See Art. 89.

RUBBER COVERED WIRE*

Stranded Conductor — **National Electric Code**

B. & S. Gauge and C. M.	Diam. Single Braid, Inches	Weight per 1,000 ft., Pounds: Single Braid	Weight per 1,000 ft., Pounds: Double Braid	Weight per 1,000 ft. Leaded	Diam. Leaded Inches	Thickness of Lead, Inches	Thickness of Rubber, Inches
16	.196	28	43	210	.290	3/64	3/64
14	.212	35	50	228	.306	3/64	3/64
12	.231	46	63	253	.325	3/64	3/64
10	.255	63	81	288	.349	3/64	3/64
8	.285	86	107	335	.379	3/64	3/64
6	.374	139	162	410	.433	3/64	1/16
5	.396	165	189	455	.455	3/64	1/16
4	.422	197	221	507	.481	3/64	1/16
3	.450	240	265	567	.509	3/64	1/16
2	.512	289	316	639	.541	3/64	1/16
1	.587	381	410	935	.647	1/16	5/64
100000	.616	447	476	1030	.676	1/16	5/64
0	.626	464	493	1055	.686	1/16	5/64
125000	.656	513	544	1128	.716	1/16	5/64
00	.669	563	595	1202	.730	1/16	5/64
150000	.690	617	650	1275	.750	1/16	5/64
000	.721	683	716	1372	.781	1/16	5/64
200000	.763	800	834	1532	.823	1/16	5/64
0000	.779	835	869	1583	.839	1/16	5/64
250000	.873	1032	1095	2047	.948	1/16	3/32
300000	.932	1218	1283	2303	1.008	5/64	3/32
350000	.976	1381	1449	2527	1.056	5/64	3/32
400000	1.027	1548	1617	2753	1.102	5/64	3/32
500000	1.113	1888	1958	3202	1.189	5/64	3/32
600000	1.222	2275	2354	3725	1.298	5/64	7/64
700000	1.294	2619	2707	4148	1.370	5/64	7/64
750000	1.328	2791	2880	4355	1.404	5/64	7/64
800000	1.360	2959	3051	4912	1.436	3/32	7/64
900000	1.423	3295	3390	5340	1.531	3/32	7/64
1000000	1.482	3624	3721	5752	1.590	3/32	7/64
1250000	1.650	4496	4600	7704	1.820	1/8	1/8
1500000	1.772	5319	5432	8754	1.942	1/8	1/8
2000000	1.992	6958	7075	10821	2.162	1/8	1/8

Note—Wire and Cable No. 1 B. & S. and larger have tape over rubber in addition to braid. Add 1/16" to single braid for diameter of double braid.

*General Electric Co.

77. Several other forms of rubber covered wire are in general use among which may be mentioned *incandescent lamp cord,* Fig. 9. This consists of a conductor composed of a

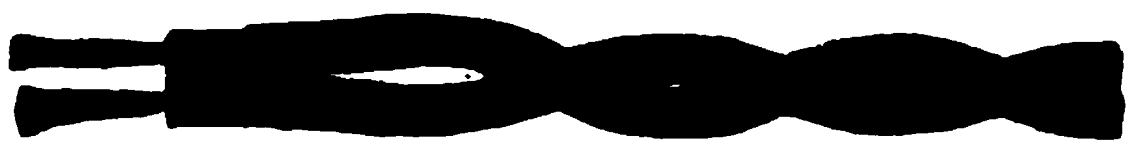


Fig. 9

number of fine wires bunched together to secure flexibility. Over the conductor is placed a tight close wind of cotton, then a covering of vulcanized rubber compound at least $\frac{1}{32}$ in. thick, followed by a cotton or silk braid. Two such wires are twisted together so that the lamp cord when completed contains both legs of the circuit.

78. *Reinforced lamp cord,* Fig. 10, is similar to the ordinary cord, except that the braid over the rubber is always of cotton

Fig. 10

and after the wires are twisted together the pair is covered with another layer of rubber and a final protecting braid. For use in moist places this braid is saturated with an asphaltum compound.

79. Gutta-percha is sometimes used as the insulating covering of conductors under conditions where it is protected from the action of light and air, as in the case of submarine cables.

80. This gum is obtained by making incisions in the bark of the branches of the Isondra gutta-tree, the sap that exudes and dries on the leaves and twigs, being scraped off and rolled into balls. The gum is shredded, washed to remove impurities, and masticated by a corrugated roller. After this it is dried and is ready for use.

81. Gutta-percha is heated and applied to the wire or strand

in a manner similar to that in which small wires are covered with rubber compound, so that a continuous uniform covering is formed. Several layers are applied in this manner and then the insulation is carefully tested to detect any mechanical imperfections in the covering.

82. Before such a conductor can be immersed in the sea it must be suitably protected by other coverings. These generally consist first of a layer of tanned jute, then a strand of galvanized wire, and finally a winding of jute yarn saturated with an asphaltum compound to protect the galvanized iron wire.

83. Paper is largely employed for insulating coverings Fig. 11, under conditions where it is protected from the action

Fig. 11

of moisture, as by being enclosed in a continuous lead sheath. The paper in the form of a ribbon is wound around the conductor helically, the desired thickness being obtained by using several layers. The turns overlap and successive layers are staggered. The covering is then carefully dried and impregnated with an insulating oil, such as specially prepared linseed oil. The best grade of Manila paper is required and it should not contain particles of iron, wood pulp, or any trace of alkali or acid. This form of insulation, when properly applied, is not injured by a continued temperature of 130 deg F.

84. Varnished cambric is another form of insulating cov-

ering, Fig. 12, that is considerably used. A layer of treated paper, cloth, or unvulcanized rubber is first applied to the con-

Fig. 12

ductor to prevent any possible action between the varnish and the copper. Over this separating layer strips of varnished, closely-woven cotton fabric are wound helically, the turns overlapping and successive layers being staggered. The strips and layers are cemented together by a non-drying, adhesive, insulating compound placed between them. This compound prevents the varnished cambric fabric from unwrapping when the cable is cut, and permits adjoining layers to slide upon each other when the conductor is bent. It also prevents the capillary absorption of moisture between the layers. The insulation, when properly applied does not deteriorate at a constant temperature of 150 deg. F

85. After the application of sufficient layers to secure the required thickness of insulation, the covering is finished with cotton braiding and weatherproofing, asbestos braiding and flameproofing, or with a lead sheath. This form of covering is not affected by moisture to the extent that paper is, and may be used indoors without a lead sheath. It is considerably more flexible than paper and mineral oils have no effect upon it.

86. Groups of two or more conductors, each separately surrounded by its own insulating covering, are frequently bunched or stranded together to form cables, Fig. 13, and protected by another insulating covering that surrounds the group. Such a cable may contain many separate circuits.

Fig. 13

When two insulated conductors are combined in this manner the group is given various names, such as *twisted pair* and

Fig. 14

duplex wire or *cable,* the name signifying some detail regarding the construction. Thus in a twisted pair, Fig. 14, the

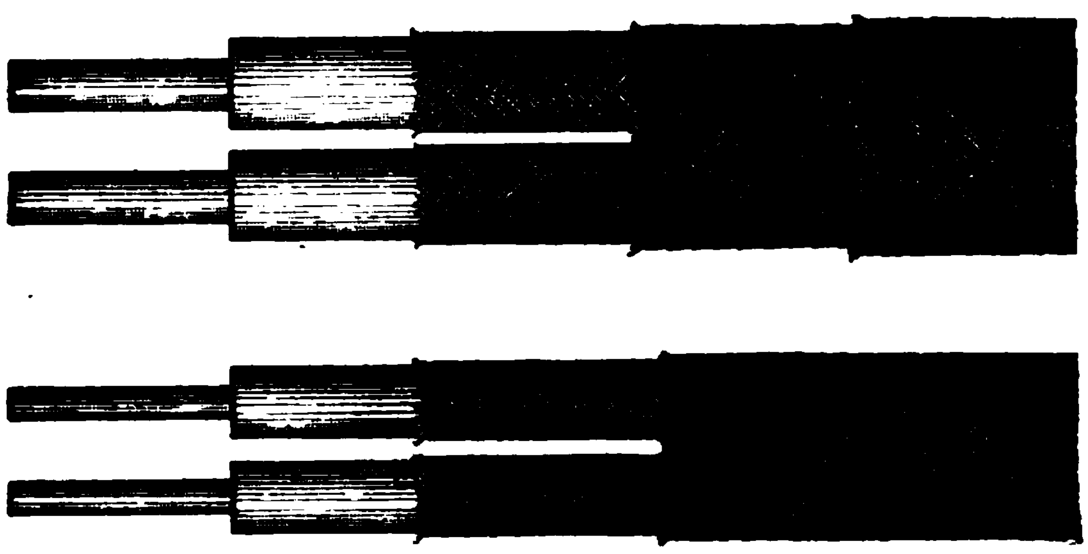


Fig. 15

two insulated conductors are twisted together, while in duplex wire, Fig. 15, they lie flat, side by side.

87. To aid in finding the *same* wire at two ends of a cable composed of *insulated* wires the insulation of one wire in each layer is often *covered with braid or tape,* the other wires being found by their location relative to the marked wire.

The wires, of cables that are composed of only a few conductors, are frequently covered with different *colored* braids or have different *colored threads* woven into the braids. Single wires are frequently marked in this manner for use when a number of them are to be run together.

88. Wires and cables that are placed beneath the ground or water require special protection to prevent injurious chemical and mechanical action upon the materials employed in their construction.

89. For underground work the protection is generally obtained by the use of a continuous, water-tight *lead sheath*, which surrounds the covering of insulating material. The sheath is applied to the insulated conductor by the use of a lead press. Sometimes a small percentage of tin is added to the lead to harden it somewhat.

90. To protect the sheath from chemical action it may be given a coating of tin, preservative paint, or covered with a braid saturated with preservative compound, the latter also serving to protect it from mechanical injury. In addition as still better protection against mechanical injury it may be provided with an armor, Fig 16, of steel tape or wire wound around it

Fig. 16

91. Although lead encased, rubber insulated conductors are sometimes employed for submarine work, a protection similar to that described in Art. 82 is more generally used.

SPECIFICATIONS AND TESTS

92. The thickness of insulation used on a conductor depends on the voltage at which it is to be operated, the size of the conductor, character of the insulating material, and conditions under which the conductor is to be employed, the proper value being determined largely by experience. It is necessary, therefore, in specifying the thickness of insulation, to also specify the character of the insulation and to designate certain tests to determine that the insulation is according to specifications. In the case of rubber covered wire various manufacturers and associations have adopted specifications and tests, which generally differ from each other only in details. The following set of specifications and tests is that adopted by the Rubber Covered Wire Engineers' Association in 1907.*

SPECIFICATIONS FOR 30 PER CENT RUBBER INSULATING COMPOUND

93. The compound shall contain not less than 30 per cent by weight of fine dry Para Rubber which has not previously been used in rubber compounds. The composition of the remaining 70 per cent shall be left to the discretion of the manufacturer.

Chemical: The vulcanized rubber compound shall contain not more than 6 per cent by weight of acetone extract. For this determination, the acetone extraction shall be carried on for 5 hours in a Soxhlet extractor, as improved by Dr. C. O. Weber.

Mechanical: The rubber insulation shall be homogenous in character, shall be placed concentrically about the conductor, and shall have a tensile strenth of not less than 800 pounds per square inch.

From any wire on which the wall of insulation does not exceed $\frac{4}{32}$ inches, a sample of vulcanized rubber compound not less than four inches in length shall be cut with a sharp knife held tangent to the copper. Marks should be placed on the sample two inches apart. The sample should be stretched until the marks are six inches apart and then immediately released: one minute after such release the marks shall not be over $2\frac{3}{8}$ inches apart. The sample shall then be stretched until the marks are 9 inches apart before breaking.

In case the wall of insulation exceeds $\frac{4}{32}$ inches, the return required shall be $2\frac{1}{2}$ inches instead of $2\frac{3}{8}$ inches, and the stretch before breaking shall be 8 inches instead of 9 inches.

*These are given in place of the Railway Signal Association specifications as the latter have not been adopted and are subject to further revision.

For the purpose of these tests, care must be used in cutting to obtain a proper sample, and the manufacturer shall not be responsible for results obtained from samples imperfectly cut.

These tests shall be made at a temperature not less than 50 deg. F.

For high tension service, it is recommended that the above mechanical requirements of the rubber be eliminated.

Electrical: Each and every length of conductor shall comply with the requirements given in the following table. The tests shall be made at the works of the manufacturer when the conductor is covered with vulcanized rubber and before the application of other covering than tape or braid.

Tests shall be made after at least 12 hours submersion in water and while still immersed. The voltage specified shall be applied for 5 minutes. The insulation test shall follow the voltage test, shall be made with a battery of not less than 100 or more than 500 volts, and the reading shall be taken after one minute's electrification. Where tests for acceptance are made by the purchaser on his own premises, such tests shall be made within ten days of receipt of wire or cable by purchaser.

Inspection: The purchaser may send to the works of the manufacturer a representative who shall be afforded all necessary facilities to make the above specified electrical and mechanical tests, and also, to assure himself that the 30 per cent of the rubber above specified is actually put into the compound, but he shall not be privileged to inquire what ingredients are used to make up the remaining 70 per cent of the compound.

VOLTAGE TEST FOR 5 MINUTES

For 30 minutes test, take 80 per cent of these figures

Size	Thickness of Insulation in Inches									
	$\frac{3}{64}$	$\frac{2}{32}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{4}{32}$	$\frac{5}{32}$	$\frac{6}{32}$	$\frac{7}{32}$	$\frac{8}{32}$
1,000,000 to 550,000	....	....	....	....	6000	8000	12000	16000	19000	22000
500,000 to 250,000	....	....	....	5000	7000	9000	13000	16000	19000	22000
0000 to 1	....	....	4000	6000	8000	10000	13000	16000	19000	22000
2 to 7	....	3000	5000	7000	9000	11000	14000	16000	18000	20000
8 to 14	3000	4500	6000	7500	9000	10000	11000	12000	.....	.....

MEGOHMS PER MILE, 60 DEG. F.
One Minute Electrification

Size	Thickness of Insulation in Inches									
	$\frac{3}{64}$	$\frac{2}{32}$	$\frac{5}{64}$	$\frac{3}{32}$	$\frac{7}{64}$	$\frac{4}{32}$	$\frac{5}{32}$	$\frac{6}{32}$	$\frac{7}{32}$	$\frac{8}{32}$
1,000,000 c. m.	....	....	....	....	300	340	420	490	560	630
900,000 "	....	....	....	....	320	360	440	510	590	660
800,000 "	....	....	....	....	330	380	460	540	610	690
700,000 "	....	....	....	....	350	400	490	570	650	730
600,000 "	....	....	....	....	380	430	520	610	690	770
500,000 "	....	....	....	360	410	460	570	660	750	830
400,000 "	....	....	....	400	450	510	620	720	820	910
300,000 "	....	....	....	450	520	580	700	810	910	1010
250,000 "	....	....	....	490	560	630	750	870	980	1090
0000 Strand	....	....	450	530	610	680	820	940	1060	1170
000 "	....	....	500	590	670	740	890	1020	1150	1270
00 "	....	....	560	650	740	820	980	1130	1260	1380
0 "	....	....	600	710	800	890	1060	1210	1350	1470
1 Solid	....	....	750	870	970	1080	1270	1440	1600	1740
2 "	....	680	820	950	1070	1170	1380	1560	1720	1870
3 "	....	750	900	1040	1160	1280	1490	1680	1850	2000
4 "	....	820	980	1130	1260	1380	1610	1800	1980	2140
5 "	....	910	1070	1230	1370	1500	1740	1940	2130	2290
6 "	....	990	1160	1330	1480	1610	1860	2070	2260	2430
8 "	950	1170	1370	1560	1720	1870	2140	2360	2570	2750
9 "	1040	1280	1490	1680	1850	2000	2280	2520	2730	2910
10 "	1130	1390	1610	1810	1990	2150	2440	2680	2890	3000
12 "	1340	1620	1860	2080	2270	2440	2750	3000	3220	3420
14 "	1550	1860	2120	2360	2560	2740	3060	3320	3550	3750

94. *Notes.* Soft-drawn annealed copper wire is generally used for insulated conductors, instead of hard-drawn wire, on account of its superior flexibility and conductivity. On account of its superior strength, however, hard-drawn insulated wire may be used for special work, such as long spans. Solid wire may be used if flexibility is not important, but stranded conductors are generally desirable for sizes larger than No. 10 B. & S. G. if they have to be drawn into conduits. When the area of conductors is 2,000,000 c. m. or more, they are generally too stiff, even in the form of a concentric strand, and therefore are often rope-laid.

Certain mechanical tests are generally specified for the purpose of determining the strength, ductility, and flexibility of the wire, and to insure that certain forms of joints may be

made and that undue stresses will be absent in the wires of a strand.

95. A conductivity of 98% Mathiessen's Standard, which is generally specified for copper conductors, is about the best that is commercially obtainable, considerable difficulty and additional expense being encountered in producing grades of higher conductivity.

96. Splices in a conductor are undesirable as they are of higher resistance than the conductor, and also are liable to break inside the insulation when the conductor is installed, producing a fault that it is difficult to locate.

97. Not more than 33% of rubber is sometimes specified to prevent the use of any other than Para rubber. If an inferior grade is used the compound will have to contain more than 33% to meet the test requirements. The inferior grades are to be avoided as their permanence is doubtful.

The amount of resinous or acetone extract is limited since its presence in greater quantities indicates the use of inferior rubber, a small amount of extract being an essential quality of fine dry Para rubber. In some cases it is recommended that the amount should not exceed 3 per cent in the gum and that the compound after vulcanization shall contain not more than 2 per cent by weight of acetone extract which is volatile below 212 deg. F.

The amount of free sulphur is sometimes limited in order to protect the copper from corrosion. It is recommended that the amount should not exceed 1 per cent.

98. The physical or mechanical tests of the rubber insulation combined with the restriction in the quantity of rubber make it practically impossible to use objectionable compounds.

99. The insulated conductor is required to be immersed for 12 hours, previous to making the insulation resistance test, to enable the water to penetrate anywhere it could penetrate after the conductor was installed. In some cases this period is in-

creased to 48 hours. Cambric insulation requires about the same period of immersion as rubber insulation, while a much shorter period is sufficient for paper, as it is very hygroscopic.

100. As the materials used in other forms of insulation, such as cambric, paper, etc., are generally of undoubted permanence and known electrical qualities, no further specifications are usually needed than a general description. They should, however, be subjected to a sufficiently high voltage test, and the insulation resistance should be great enough for successful operation.

EXAMINATION QUESTIONS

(1) What three metals are most used as conductors for transmission purposes?

(2) Why is it not economical to use insulated aluminum conductors, for transmission purposes, provided that the cost of the metal for equal conductivity is the same?

(3) A transmission line of given length requires bare wire of such a size that a certain conductivity will be obtained. Which is more economical to buy copper at 25 cents per lb. or aluminum at 33 cents per lb.?

(4) A copper cable with a cross-sectional area of 100,000 c. m. is required to conduct a given current with a certain drop in voltage. What would be the approximate area of a cable of commercial iron wire that would conduct the current with the same drop?

(5) How are iron and steel wire prevented from rusting?

(6) Under what general condition is it advantageous to use copper-clad steel wire?

(7) State the difference between the conductivity and tensile strength of hard-drawn and soft-drawn or annealed copper wire.

(8) Why is copper wire sometimes tinned?

(9) What is a concentric strand?

(10) Name four different insulating materials that are placed on magnet wire.

(11) How does office wire differ from magnet wire?

(12) Why is the asphaltum compound used to saturate the covering of weatherproof wire, superior to paraffine?

(13) To what process must rubber insulating compounds be submitted to render them durable and prevent ordinary temperature changes from affecting them?

(14) Why does rubber produce such a desirable insulating covering?

(15) Why is the rubber generally protected by an outer covering of some other material?

(16) Why do paper insulating coverings require a lead sheath?

(17) When several insulated wires are made up into a cable, what simple method is frequently used to enable the same wire to be found at each end of the cable?

(18) What is meant by an armored cable?

(19) State the reason for limiting the amount of acetone extract in rubber.

(20) Why are insulated conductors immersed in water previous to testing for insulation resistance?

LINE CONSTRUCTION

1. In order to employ wires and cables for the purpose of transmitting electrical energy from one point to another, they must be properly supported. That is, they must not only be properly insulated from the ground and from one another, but must be supported so as to both protect them from injury, and prevent them from causing injury. Wires or cables when supported in this manner form what are known as **lines** or **transmission lines.**

2. **Lines** may be divided into three general classes known as **aerial** or **pole lines, underground** or **duct lines,** and **submarine lines,** according as they are run through the air, earth, or water. Of these, *aerial* lines are used to the greatest extent. *Underground* lines, on account of their greater cost, are generally used only where it is impossible or undesirable to employ aerial lines, and *submarine* lines become necessary when the width of a body of water is too great to allow aerial construction, or when aerial lines are not practical on account of the height of passing vessels.

AERIAL LINES

3. This type of construction consists in running the wires or cables through the air, at a suitable distance above the ground, and supporting them by poles, or in some cases towers, which are provided with the necessary cross-arms and other devices, for attaching and insulating the conductors. Available buildings or other structures may also be used as supports.

OPEN WIRE LINES

MATERIALS OF CONSTRUCTION

4. Wire: The principal kinds of wire used for *open wire lines* are *bare copper* and *iron*, and *weatherproof copper*, *copper-clad*, and *iron*. Of these No. 10 and 12 B. & S. G. weatherproof hard drawn copper wires are generally used, except when larger sizes are necessary to conduct the required current. The sizes of iron wire ordinarily used are No. 4 to 10 B. W. G. and those

The School of Railway Signaling wishes to thank the Western Electric Co., the Central Electric Co., Bissell & Co., and others who have contributed cuts and information to be used in compiling this text.

of copper-clad No. 12 and 14 B. & S. G. *Rubber covered copper wire* is usually employed for making connections from the line to signal devices.

5. **Poles:** *Wooden poles* are used to the greatest extent for the support of aerial lines. Various kinds of wood are used, of which cedar is believed to be the best; followed by chestnut, cypress, Norway pine, redwood, etc.; the kind of wood depending to some extent on what is available in the locality where the poles are to be used. Thus redwood would be mostly used in the western states, as it grows in that section of the country.

6. Trees from which poles are made are cut in the winter months, trimmed, the bark removed, and the butts squared. They are then piled to season with open spaces between them, and in a position raised above the ground. The period of seasoning continues for at least a year or eighteen months. Only live growing timber, sound and free from shakes* and undesirable knots, is used, and trees are selected that are well proportioned and free from objectionable bends.

7. The size of poles is usually specified by the length in feet and the circumference at the top in inches. The circumference is generally used instead of the diameter, on account of the fact that the tops are seldom round and several different diameters may be measured. In addition the circumference six feet from the butt is specified in some cases, to insure that poles have the proper taper.

8. Poles generally vary in length by 5 feet. A top circum-

SIZES AND WEIGHTS OF WOOD POLES

Length in Feet	Circumference in Inches		Approximate Weight in Pounds	Length in Feet	Circumference in Inches		Approximate Weight in Pounds
	At Top	6 ft. from Butt			At Top	6 ft. from Butt	
25	22	30	325	45	25	46	1080
25	25	34	415	50	22	46	1120
30	22	34	450	50	25	50	1390
30	25	37	560	55	22	50	1400
35	22	37	580	55	25	54	1550
35	25	40	700	60	22	54	2000
40	22	40	750	60	25	58	2400
40	25	43	900	65	22	58	2700
45	22	43	900	70	22	64	3400

*See Materials.

ference of 25 in. is usually employed although poles with a 22 in. top may be used where only a few wires are to be supported. For six wires or less top circumferences smaller than these are sometimes employed. The table gives the ordinary pole sizes.

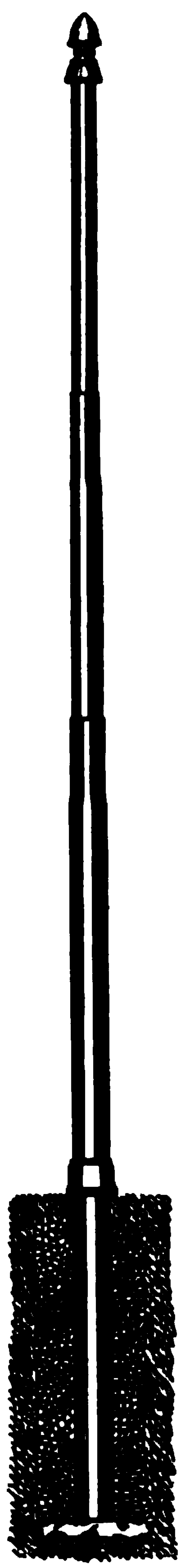


Fig. 1

9. Owing to the increasing scarcity of timber and to the cost of replacements, various methods of treating poles to increase their life are used to some extent. One of these methods consists of saturating the wood with creosote, while others involve the use of zinc chloride or other chemicals.

10. As the pole decays more quickly at and just below the surface of the earth, where it is alternately wet and dry, there is some advantage in coating the butt with pitch before placing it in the ground, and in charring it previous to applying the pitch. In some cases poles are protected at this point by enclosing them in concrete.

11. For heavy lines *steel poles* are used to a limited extent. Various forms of construction are employed, such as special formed pipe, Fig. 1. Pipe poles are commonly made of from two to four pieces of successively decreasing diameters, shrunk, welded, or screwed together.

12. Poles made of *reinforced concrete* are under trial at the present time. Such poles are very heavy, but have the advantage of a very long life.

13. A wooden pole, as ordinarily fitted for low tension lines, is illustrated in Fig. 2, the names of the various fittings being given beneath it.

14. Referring to the term *low tension* lines*, there is no exact point of division between low and high tension lines. In a general sense lines operating at voltages below 2,200 volts may be considered as low tension lines, and those operating at this or greater voltages as high tension lines.

*Sometimes called *low potential*.

The term as here used, however, means lines working at the voltages most commonly used in signal work; namely seldom exceeding 50 or 55 volts. Higher voltages are employed, of course, such as 110 volts used in electric interlocking and even 500 or 600 volts used on storage battery charging lines as employed in block signal work, the same general methods of construction being used in these cases, only that more attention is given to insulation and to making joints.

15. **Guys:** *Guys* are wires either solid or stranded* which are generally run from a support fixed in the earth to the top of a pole, to strengthen it against side, or end

Fig. 2

1—*Cross-arm*
2—*Cross-arm braces*
3—*Wood pole step*
4—*Iron pole step*
5—*Insulator pin*
6—*Insulator*

*The term *strand* is often used instead of stranded wire.

stresses. Wire for this purpose is generally made of galvanized steel.

16. It is common practice to fasten the guy at the earth end to a $\frac{5}{8}$ in. galvanized iron **anchor rod** or **guy rod,** Fig. 3, which is

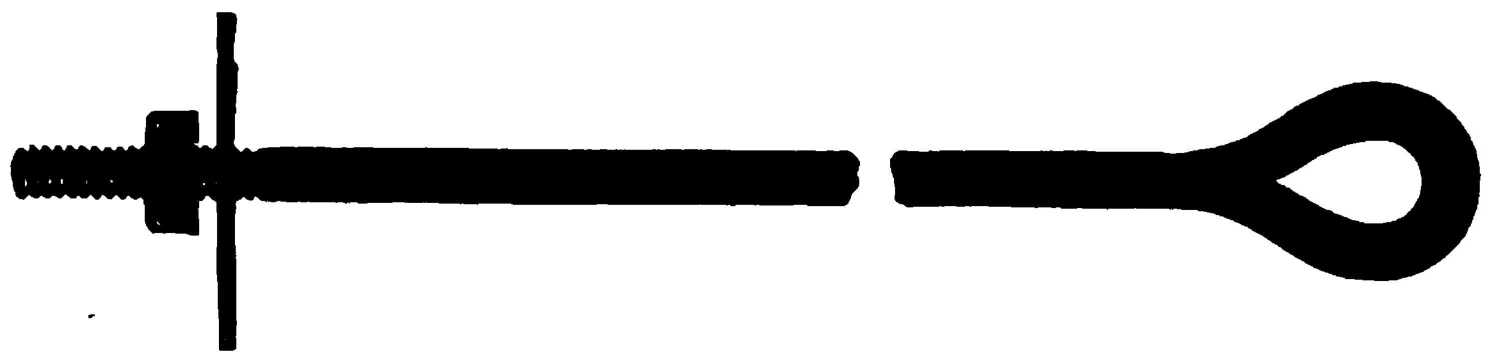


FIG. 3

bolted to a piece of timber, known as an **anchor log,** or to any other suitable **anchor** such as a concrete block, buried in the ground. Anchor logs are generally made by cutting up crooked poles. Various forms of **folding** and **screw anchors,** Fig. 4, may be obtained to take the place of this construction. In places

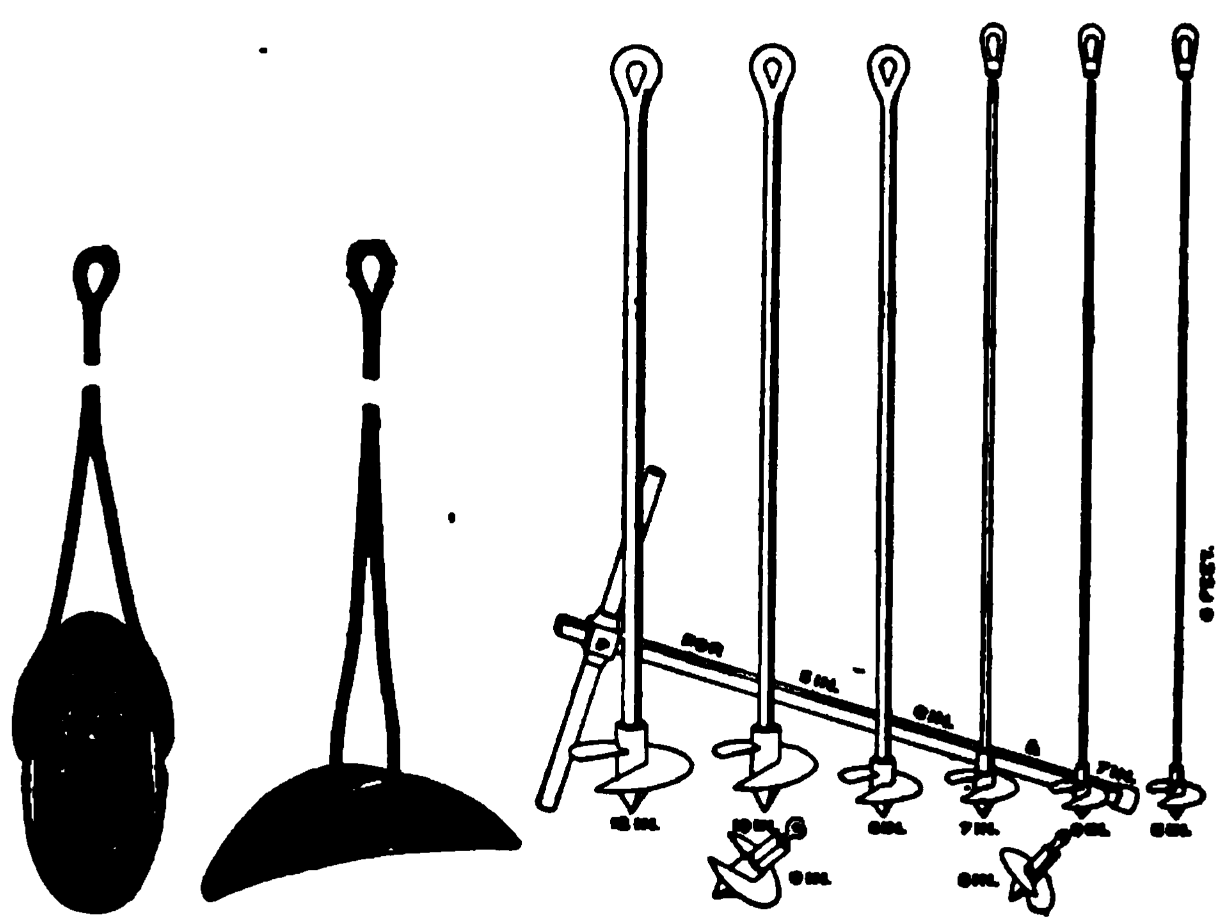


FIG. 4

where rock is encountered **rock bolts** or **anchors,** Fig. 5, are used to anchor the guy.

17. If stranded guys are used the ends where attachment is made to the pole or anchor rod are secured by **guy clamps,** Fig.

6, or **wire rope clips,** Fig. 7. Both of these devices, in several different forms, are made of galvanized iron.

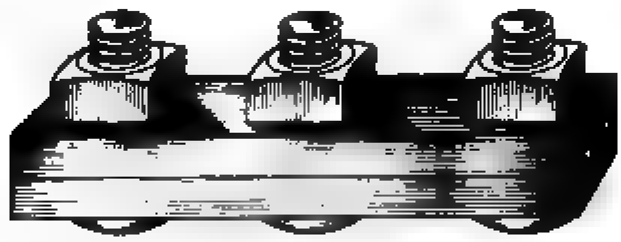


Fig. 5 Fig. 6

18. To prevent the guy from slipping where it is wrapped

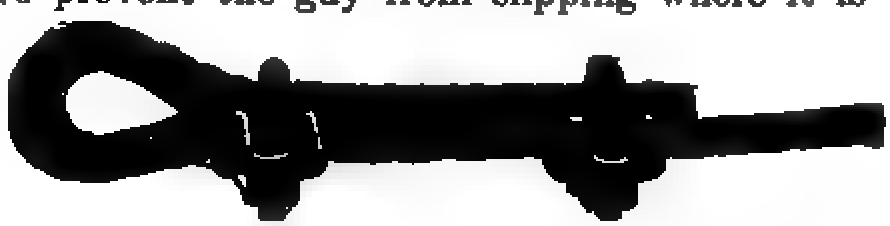


Fig. 7

around the pole, a galvanized iron **guy hook,** Fig. 8, may be used. It is fastened to the pole with spikes or lag screws.

19. Instead of wrapping the guy around the pole, it may be fastened to a galvanized iron **eye bolt,** which is passed through the pole. Eye bolts may also be used for fastening the other end of the guy to a guy stub or structure.

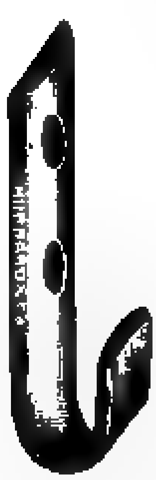


Fig. 8

20. When a solid or stranded wire is fastened to an eye bolt or anchor rod, it should be protected by a **wire rope thimble,** or **wire eye,** Fig. 9, which is applied as shown in Fig. 7. These are generally made of galvanized iron.

Fig. 9

21. A galvanized wrought iron **turnbuckle,** Fig. 10, may form part of a guy, in case it is desirable to adjust the tension. These

Fig. 10

are sometimes fitted with porcelain insulators, as shown in Fig. 11.

Fig. 11

22. Pole clamps or **pole bands** of galvanized iron, Fig. 12, while they may be used on wooden poles for fastening guy wires, are more generally used on steel pipe poles.

23. Cross-arms: Several conductors are generally supported by a pole, and in order to place the proper spaces between them, *cross-arms* are used to carry the pins and insulators to which the conductors are fastened. Cross-arms are rectangular pieces of wood, Fig. 13, long leaf yellow pine and Washington fir being considered best for this purpose. The wood should be sound, well seasoned, straight grained, and free from knots. Cross-arms are carefully formed to certain sizes and

Fig. 12

Fig. 13

slightly rounded at the top except for a short distance at the

center where they fit the pole, so that they will readily shed water.

24. Among a number of sizes employed that known as the *standard cross-arm*, measuring 3¼ in. x 4¼ in., is in most general use. A lighter arm, measuring 2¾ in. by 3¾ in., sometimes called the *telephone cross-arm*, is used to a limited extent.

The lengths of cross-arms depend upon the number of pins they are to hold.

25. The following table gives the lengths, etc., of standard cross-arms.

STANDARD CROSS-ARMS

Finished size, 3¼ in. x 4¼ in.

Bored for 1¼ in. or 1½ in. wood pins, or for ½ in. or ⅝ in. steel pins, two ⅜ in. carriage bolts, and one ⅝ in. center bolt or two ½ in. lag screws, as may be directed.

Pin holes are of a size to give a driving fit; carriage bolt holes, 7/16 in. diameter; ½ in. lag screws or machine bolt holes, 9/16 in. diameter; and ⅝ in. machine bolt holes, 11/16 in. diameter.

Length in Feet	No. of Pins	Pin Spacing*			Approx. Weight in Pounds
		Ends, Inches	Centers, Inches	Sides, Inches	
3	2	4	28	..	10
4	4	4	16	12	14
6	4	4	20	22	21
6	6	4	16	12	21
8	6	4	19	17¼	28
8	8	4	19	11½	28
10	8	4	19	15½	35
10	10	2½	16	12⅜	35

26. To prevent decay cross-arms are frequently protected by painting them with an oil paint, but in many cases are used unpainted.

27. Cross-arms made of steel angles or malleable iron, are sometimes used in place of wood arms, especially on power transmission lines.

28. **Side Arms:** In some cases it is necessary to attach the

**Ends*—This is the distance between the end pins and the ends of the arm. *Centers*—This is the distance between the two center pins. *Sides*—This is the distance between other pins. The spacings given are used as standards by several roads; other values, however, are sometimes employed.

arms to the pole at one end, instead of at the center. Such arms are called **side** or **alley arms**,* Fig. 14, and the squared part that fits the pole is placed either at the end, as shown, or between the second and third pin hole. With the latter arrangement the cross-arm braces, Art. 29, are placed on the opposite side of the pole, as shown in Fig. 18.

29. Cross-arm Fastenings: Cross-arms are attached to the poles by means of two $\frac{1}{2}$ in. x 7 or $7\frac{1}{2}$ in. galvanized lag screws, or one $\frac{5}{8}$ in. galvanized center bolt. In addition they are generally braced by two bars of galvanized iron known as **cross-arm braces**, Fig. 15, each of which is bolted to the cross-arm, Fig. 16, by a $\frac{3}{8}$ in. galvanized carriage bolt, which should be

Fig. 14

Fig 15

about $\frac{3}{4}$ in. longer than the thickness of the arm. Both braces

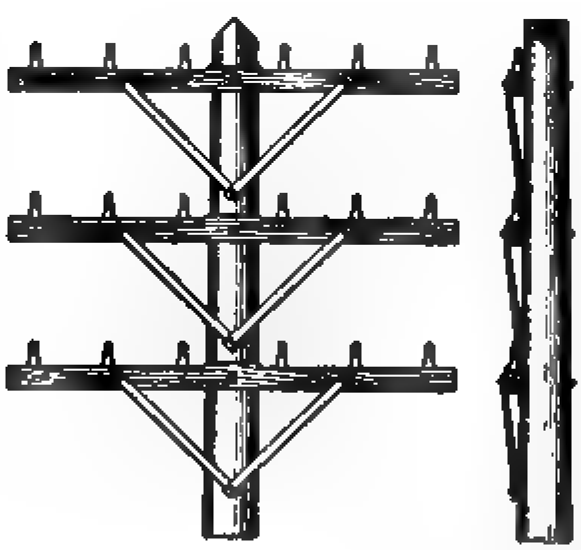


Fig. 16

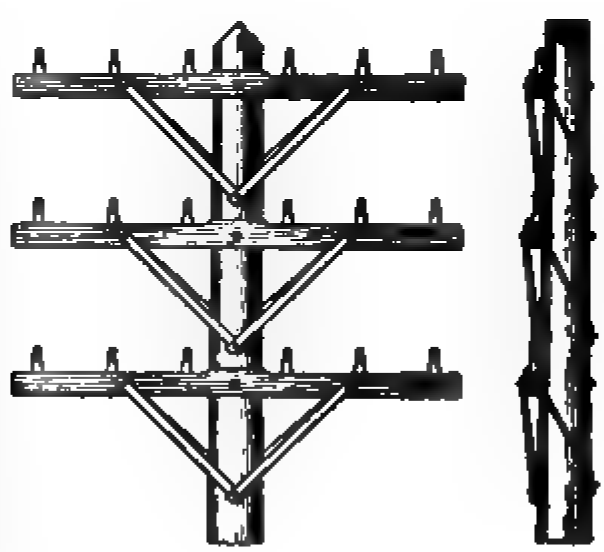


Fig. 17

*Also called *extension fixtures* or *extension arms*.

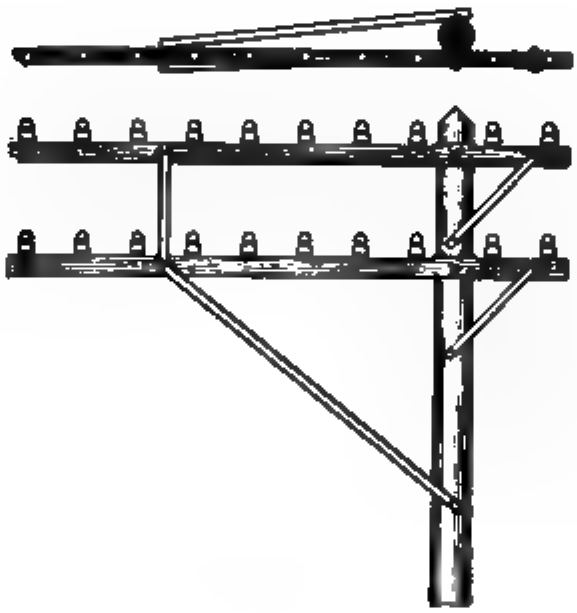


FIG. 18

are fastened to the pole by a ½ in. x 4 in. galvanized lag screw. In some cases four cross-arm braces, Fig. 17, are used instead of two, the extra braces being called **back braces.** The following table gives the dimensions of various cross-arm braces.

CROSS-ARM BRACES

Dimensions in inches.

Length	Width	Thickness
20	1	$\frac{3}{16}$
20	$1\frac{7}{32}$	$\frac{7}{32}$
22	1	$\frac{3}{16}$
22	$1\frac{7}{16}$	$\frac{7}{32}$
24	$1\frac{7}{32}$	$\frac{7}{32}$
26	$1\frac{7}{32}$	$\frac{7}{32}$
28	$1\frac{7}{32}$	$\frac{7}{32}$
30	$1\frac{7}{32}$	$\frac{7}{32}$

30. Side and alley arms must be provided with special braces, Figs. 14 and 18, which are made in various ways, frequently of 1½ x 1½ x ¼ in. or 2 x 2 x ¼ in. galvanized *angle iron,* the arms being held at the proper distance apart by vertical braces as shown.

31. Various other special braces are used, such as the **terminal pole back brace,** Fig. 19, also called a **double arming brace** on account of the fact that it serves a purpose similar to that for which double cross-arms, Art. 32, are used. These braces are often made of galvanized angle iron.

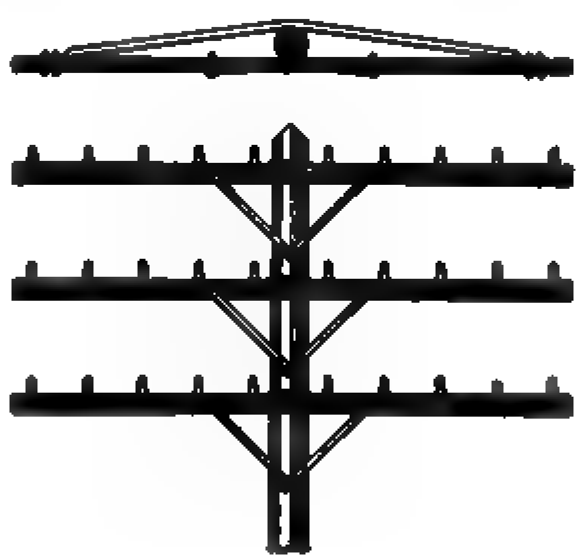


FIG. 19

32. Double Cross-arms : When it is necessary to provide extra strength the pole is double armed; that is, two cross-arms, Fig. 20, placed on opposite sides of the pole are used. These arms are fastened together at the ends by ordinary bolts and separating blocks as shown, although in some cases two bolts are used at each end. Special bolts, Fig. 21, known as **double arming bolts** or **stud bolts** are sometimes used in place of the preceding construction.

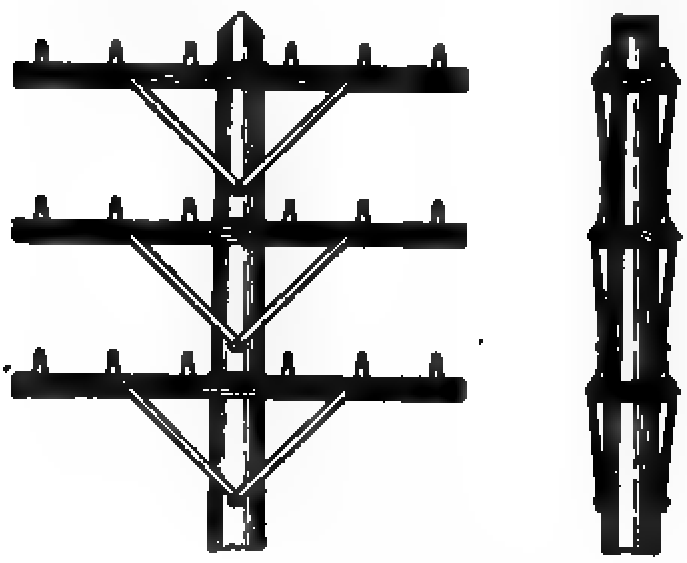


Fig. 20

33. Insulator Pins: The insulators, Art. 40, to which the wires of an aerial line are attached, are held in place on the cross-arms by means of wood, iron, or steel pieces, Fig. 22, called **insulator pins.***

Fig. 21

34. *Wood insulator pins* are generally made either of locust or oak, the former being considered better, and for the purpose of adding to their life they are often painted, mineral paint being preferred, or boiled in some insulating material, such as oil or paraffine. At the lower end they have a slightly tapered cylindrical shank which fits a hole in the cross-arm, and at the upper end they are provided with a coarse screw thread, by means of which the insulators are attached.

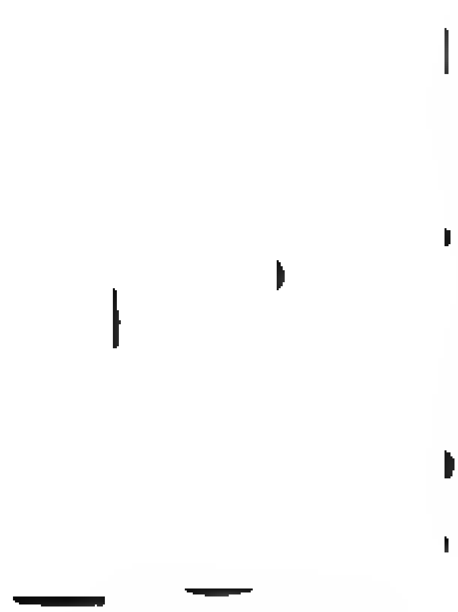


Fig. 22

*Often simply called pins.

35. *Iron and steel insulator pins* are made in a variety of shapes and, although generally provided with a threaded top of wood, are sometimes fastened into the insulators with plaster of paris or cement, or made with a threaded top of porcelain or metal, onto which the insulator may be screwed. Metal threads may be provided with a felt packing to prevent breakage by expansion.

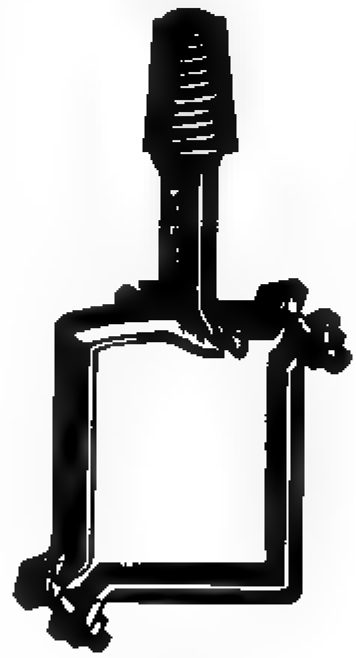


Fig. 23

Iron pins may be obtained with clamps, Fig. 23, which fit around the cross-arm, so that the hole is avoided, thus adding to the strength of the arm.

36. Three kinds of pins are in general use; *ordinary line pins*, *terminal* or *corner pins* and *transposition pins*. *Ordinary line pins* are usually made $7\frac{3}{4}$ in. or 8 in. in length with shanks, in the case of wood pins or iron of similar design, $1\frac{1}{4}$ in. or $1\frac{1}{2}$ in. in diameter. *Terminal* or *corner pins* are made for use where greater strength is required. Wood corner pins are frequently arranged with bolts extending their entire length and provided with nuts and washers at the lower end to prevent the pins from pulling out of the cross-arm. *Transposition pins* are made 9 in. long and have longer threads than the other pins for the purpose of supporting *transposition insulators* which are described later.

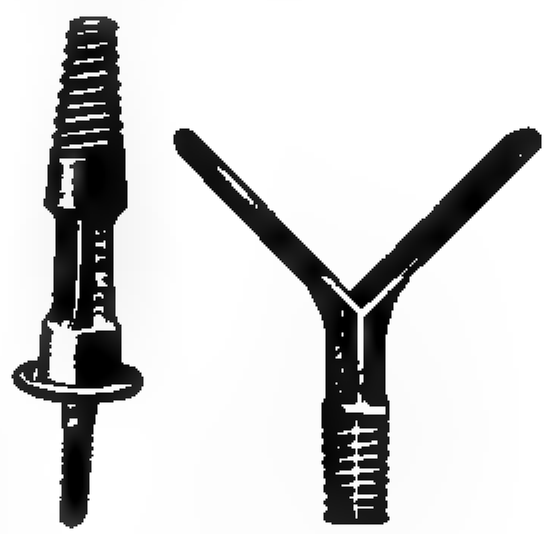


Fig. 25

37. Brackets: When the number of wires to be supported by a pole does not exceed one or two, **pole brackets,** Fig. 24, are generally used instead of cross-arms and pins, to support the insulators.

Fig. 24

These are usually made of oak, and are sometimes painted with metallic paint.

Fig. 25 shows two styles of malleable iron brackets, which may be used on the tops of poles. Fig. 26 shows a form of bracket known as a **break arm,** which is sometimes used in running branch lines. It is fastened to a cross-arm in the same manner as an insulator pin, and may be arranged for attachment to a pole top..

FIG. 26

38. Brackets are also made for the purpose of supporting wires on buildings and other structures, the malleable iron **wall brackets,** Fig. 27, being examples. They are attached by bolts, lag screws, or expansion bolts, depending on the kind of material to which they are fastened. These brackets may also be used as pole brackets.

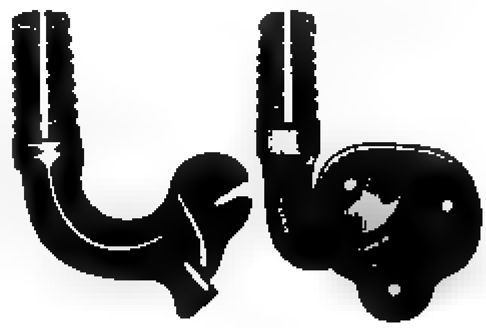


FIG. 27

39. When wires pass through trees they may be supported by insulators attached to swinging brackets, Fig.28, known as **tree brackets**; or by **tree insulators,** Fig. 29. Both of these devices are made in several different forms.

40. Insulators: To prevent electrical energy from passing through the supports from wire to wire, or to the ground, it is necessary to

FIG. 28

carry the conductors on **insulators.** These are generally made of *glass* for low tension circuits, although sometimes of *porcelain.* Glass is lower priced than porcelain although the latter is stronger, and if well made, has better insulating properties.

Fig. 29

41. *Glass insulators* for low tension lines are made in a variety of forms. Fig. 30 shows an insulator with a *single petticoat* and Fig. 31 an insulator with a *double petticoat.*

The object of the petticoats is to form a series of concentric grooves and ridges on the under side of the insulator, thus increasing the extent of surface that current must leak over before it can reach the pin, and therefore improving the insulating qualities of

Fig. 30

Fig. 31

Fig. 32

Fig. 33

the insulator. In addition, these grooves, being on the under side, will keep comparatively dry during a rain storm.

Fig. 34

Fig. 35

Among a great many forms of insulators are the **regular**, Fig. 32; the **Western Union**,.Fig. 33; the **deep groove**, Fig. 34; the

Fig. 36

Fig. 37

double groove, Fig. 35; the **single piece transposition**, Fig. 36; and the **two piece transposition** or **Hibbard insulator**, Fig. 37.

42. Rubber hook insulators, Fig. 38, consisting of a metal hook supported in an insulating base of hard rubber, threaded so that it may be screwed into a hole, are sometimes used for attaching wires to the side of a building, or for carrying them on the under side of cross-arms.

43. Porcelain knobs, Fig. 39, are used for supporting wires on cross-arms, on the sides of buildings, etc.

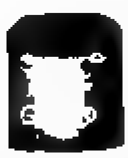
44. Porcelain split knobs, Fig. 40, are used for the same purpose as the knobs shown in Fig. 39.

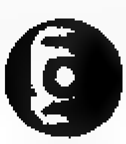
Fig. 38

45. Wire guards or **guard irons,** Fig. 41, are made in several different forms of wrought or malleable iron, and are preferably galvanized.

Fig. 39

They are placed at corners, curves, or other locations, where there is a possibility of the wire becoming detached and falling, on account of the breaking of the insulator or pin. They are particularly desirable, if the wire in falling is liable to come into contact with other circuits, or cause damage of any kind, as by hanging too low over tracks.





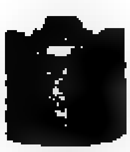


Fig. 40

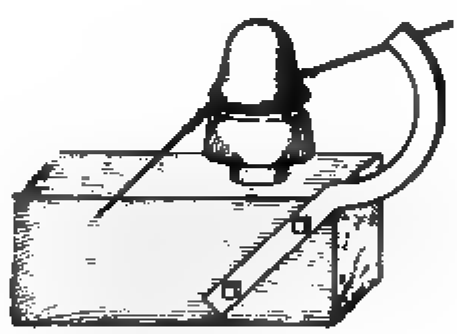


Fig. 41

46. Bridle rings or **distributing rings,** also called **pig tail hooks,** Fig. 42, are used for carrying wires from one position to another along the cross-arms. They are sometimes made closed and in some cases are fitted with porcelain nsulators. They may be either galvanized or enameled.

47. Pipe clips or **straps,** Fig. 43, covered with friction tape, see Art. 66, and **spider wire cleats,** Fig. 44, are also used or carrying wires along the cross-arms.

48. Trunking: This name is given to grooved lumber (see Fig. 59) used for the purpose of protecting wires. It is gener-

ally provided with a board cover called **capping.** Trunking is made of various woods, such as white pine, cypress, fir, etc., and comes in lengths of from 10 to 17 ft. It is sometimes treated with creosote or other wood preservative.

49. Pole Steps: These are fittings of galvanized iron or wood, Fig. 45, which are sometimes attached to a pole to aid in climbing it. They are made in a variety of forms. Wooden steps are generally used at the bottom of a pole for a distance of about 9 ft. from the ground, as they are less liable to injure a person accidentally coming into contact with them.

Fig. 43

Fig. 42

Fig. 44

Fig. 45

50. Pole rings* are made of wrought iron or mild steel, Fig. 46, about 1 in. wide by ¼ in. thick. They are placed around the tops of poles to provide extra strength, if considered desirable.

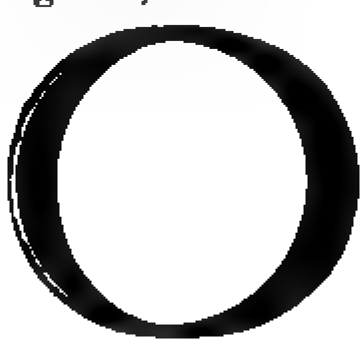


Fig. 46

51. Anti-hum Devices: These consist of two metal parts, Fig. 47, separated by a rubber cushion, and are sometimes placed in lines running into buildings to absorb vibrations. As the device is an

*This name is also used for a device employed in telephone work to support a number of insulators around a pole.

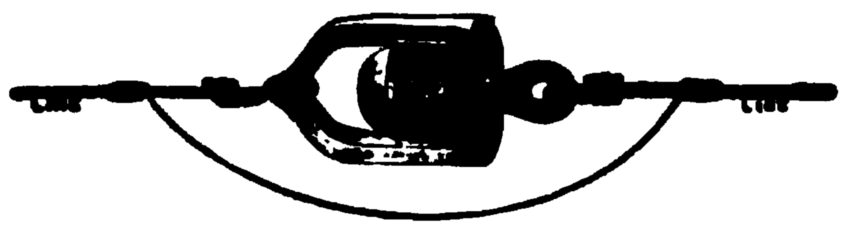


Fig. 47

insulator the line must be bridged around it as shown.

52. Porcelain Tubes: Tubes of this material, Fig. 48, are used to insulate wires where they pass through the walls of buildings. They are sometimes called **window tubes** or **weather protectors.**

Fig. 48

53. Wire Connectors: These are also called **wire joints, sleeves,** and **sleeve connectors.** Those of the *McIntyre* and *American* types, Fig. 49, consist of double tubes of the same material as the wires to be joined, the tubes being brazed together. The size of the tubes is such that they will just slip onto the wires. After the wires are in position both connector and wires are twisted for several turns as shown in Fig. 50. This operation causes the connector to grip the wires tightly. For this reason corrosion does not occur, so that a good electrical contact is maintained without the use of solder. On this account joints made with connectors are seldom soldered.

54. In case it is desired to join the end of one wire to the middle of another without cutting the latter, connectors with one of the tubes split, as shown in the illustrations, are used. The split tube is placed over the *through* wire after inserting the end of the *branch* wire in the other tube, and the connector

Fig. 49

twisted in the regular manner. The operation of twisting has the effect of closing the split tube, and causing both this and the

other tube to grip their respective wires tightly.

55. When wires of different sizes are to be joined by connectors, the tubes are made, as shown, of corresponding sizes.

Connectors for iron and steel wires are made of soft steel and tinned to prevent rusting.

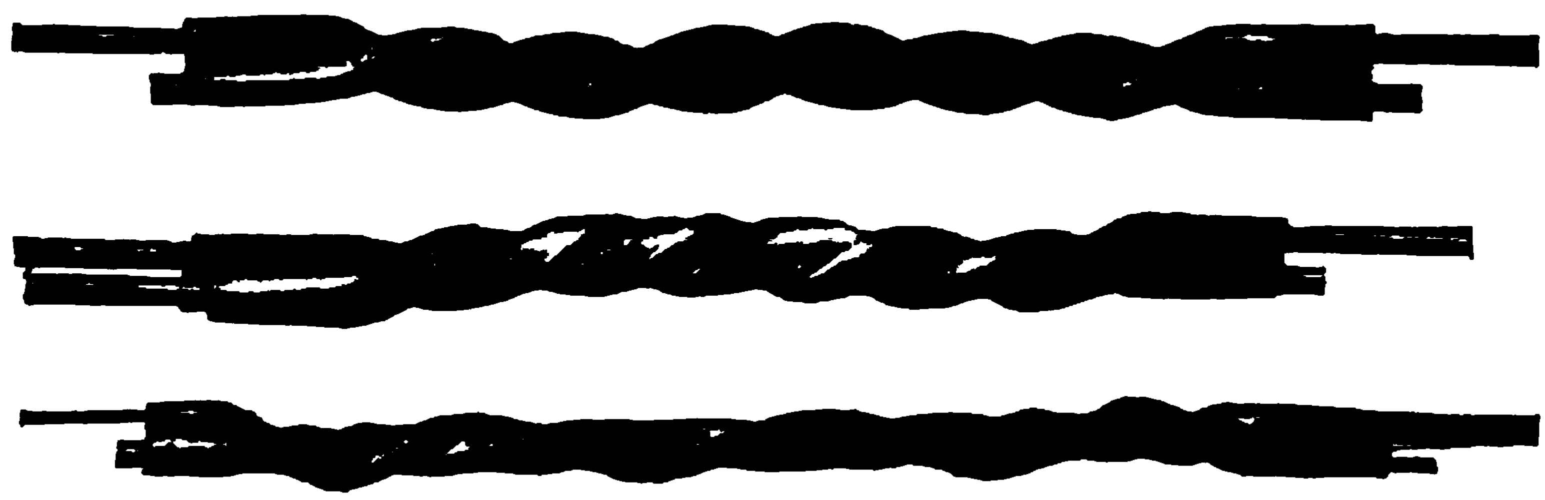


Fig. 50

Half connectors, which are one-half the length of regular connectors, are used in certain cases which will be described later.

56. Another type of connector is the *Cook*, which consists of a single tube of special form, instead of two tubes. Fig. 51 illustrates two sections of this connector, one before and one after twisting, showing how the operation of twisting causes the walls of the connector to wrap tightly around the wires.

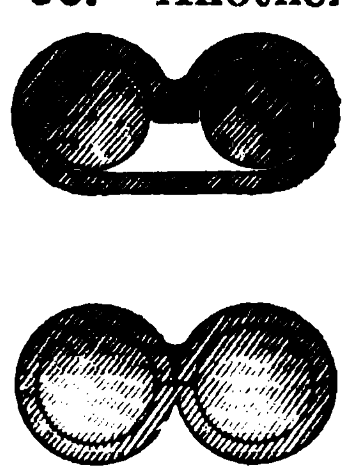


Fig. 51

Fig. 52 shows still another type of connector known as the *Premier*. This consists of a single oval tube in which both wires are placed. The operation of twisting, as with the other connectors, causes the walls

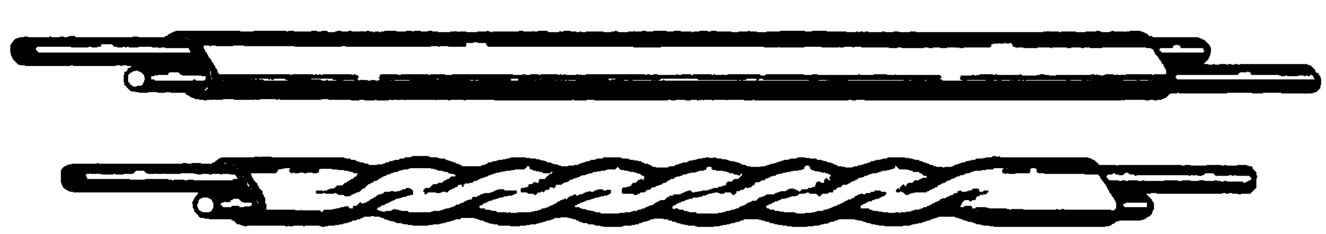


Fig. 52

of the tube to wrap tightly around and even draw down into the V-shaped space between the wires.

Fig. 53

58. Fig. 53 shows a device, known as a **test connector,** which is used for connecting wires temporarily. It is desirable that such connectors be constructed so that they will not nick the wires.

59. Lightning Arresters: Fig. 54 shows an arrester composed of concentric brass tubes held apart by porcelain insulators. The line wire is tied firmly against the outside tube with a tie-wire passing through the center of the arrester, while the inside tube is grounded by a copper wire soldered to its inside surface. The air gap or spark gap between the tubes furnishes a path to the ground, of high resistance, but practically no inductive reactance. This arrester is designed to be placed directly on the line at a pole, as shown in Fig. 55.

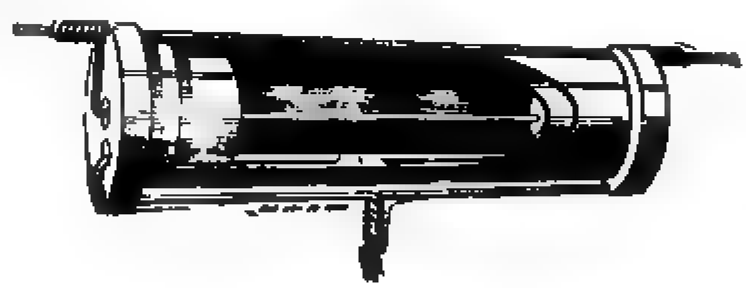


Fig. 54

Fig. 55

60. Fig. 56 shows a type of arrester which consists of a ser-

ies of rings with inwardly projecting points, mounted concentric with a cylindrical core of carborundum, so as to leave a small air gap between the points and the core. The rings are punched from sheet metal and are placed on top of one another. Every other ring is made of aluminum, those located between being made of brass. On top of the rings an aluminum cover plate is placed, an air gap being provided between it and

Fig. 56

the top of the core, which is moulded to form a series of upwardly projecting points The metal rings are fastened together with suitable bolts, which also hold the cover in position, and a perforated mica disk is placed between the top of the

Fig. 57

core and the cover plate. The bottom disk is provided with two projecting ears, as shown in the diagram, Fig. 57, connecting to binding posts. By means of one of these binding posts the disks may be connected to the line, while the core is connected to the ground by means of another binding post. The diagram, Fig. 58, shows

Fig. 58

the arresters connected *in series* with the line and employing fuses.

The arrester just described provides a path to the ground of high resistance and little inductive reactance, and in addition tends to extinguish any arc that may follow a discharge.

61. Lightning arresters may be mounted in a weatherproof iron or wood box placed on the pole or cross-arms. An iron box for this purpose is shown in Fig. 59.

Fig. 59

62. Fig. 60 shows a lightning arrester of the *choke coil type.* It consists of several turns of tinned copper wire 1, wound on a porcelain tube 2, which contains a soft iron core 3. A ground plate 4 is provided which affords a path from the coil through the air gap to the ground.

SECTION A-A

Fig. 60

63. The *ground wire* from a lightning arrester may be connected to the earth by means of a ground plate as described in *Magnetism and Electricity*. This plate should be made of a sheet of annealed copper at least 18 in. square and $\frac{1}{16}$ in. thick. A bare copper wire from 10 to 20 ft. long, not smaller than No. 6 B. & S.

G., is soldered or brazed to the plate, and the plate and wire thoroughly tinned to prevent corrosion.

64. Another method of making a ground connection is to drive a pipe or rod, Fig. 61, into the earth, and connect and solder the ground wire to it. The pipe or rod should be of gal-

Fig. 61

vanized iron about 5 to 8 ft. long. Either 1 in. pipe, or rod from ½ to 1 in. in diameter may be used.

65. Tapes: Several different kinds of tape are used in making joints in insulated wires.

66. *Friction tape* consists of a cloth strip impregnated or filled with an adhesive compound. The better grades of this tape, such as *Grimshaw* and *Manson* are filled with a rubber compound, while the lower priced tapes are filled with a non-rubber, weatherproof compound.

67. *Rubber tape* is made in several different varieties. Among these may be mentioned pure rubber splicing strips. These, as their name implies, are strips of pure sheet rubber containing no sulphur. Rubber tape, sometimes called rubber compound, such as *Okonite tape,* is made of a rubber compound without fabric, which when heated slightly, as by the warmth of the hand or a lighted match, adheres strongly forming practically a solid, moisture-proof mass.

68. *Kerite tape* consists of a cloth strip heavily coated with a rubber compound and is designed to take the place of both rubber tape without fabric and friction tape. It has long life and the property of congealing together to make a water-tight joint.

69. Liquid Insulating Materials: *Rubber cement* is simply pure gum rubber dissolved in a suitable solvent. *P. & B. electrical compound* consists of insulating materials dissolved in a solvent that evaporates rapidly, leaving a hard, glossy, adherent coating, that is claimed to be moisture, acid, and alkali proof.

P. & B. black air drying varnish drys in about 30 min., forming a tough elastic coating that repels water, sleet and snow.

CONSTRUCTION TOOLS

70. Excavating and Earth-handling Tools: The following tools are generally employed for digging holes:

The **digging bar*** is used for loosening hardened earth, gravel, etc., and is made of 1 or 1⅛ in. octagonal steel from 6 to 8 ft. long. Similar tools for the same purpose are known as the **loy**

Fig. 62

and **spud digging tools,** Figs. 62 and 63. **Round pointed shovels*** with 5 and 7 ft. straight handles and **post hole spoons,** Fig. 64,

Fig. 63

with 8 ft. handles, are used for removing earth from the hole. In certain kinds of soil, which will allow their use, **post hole augers*** afford a quick way of digging holes. **Short handle shovels*** are used when starting holes and together with **tamping bars**** Fig. 65, are used for filling in around erected poles.

Fig. 64

Fig. 65

71. Pole Erecting Tools: The following tools are those generally used in erecting poles:

Fig. 66

Pike poles, Fig. 66, are wooden poles 1¾ to 2½ in. in diameter,

*See **Tools.**
Also called *tamper* and *rammer*, see **Tools.

and varying in length from 12 to 18 ft. They are provided with a pike of pointed steel at one end, projecting about 3½ in.,

Fig. 67

this end of the pole being prevented from splitting by a ferrule.

The raising fork, Fig. 67, may be used instead of a pike pole.

Fig. 68

72. The **pole support** or **dead man,** Fig. 68, is constructed of a strong oak or hickory pole 6 to 8 ft. long, provided with an iron fork at one end with a sharpened projection in the center to prevent slipping. The other end is protected by a ferrule and sometimes armed with a spike. Another type known as the **jenny pole support** is shown in Fig. 69.

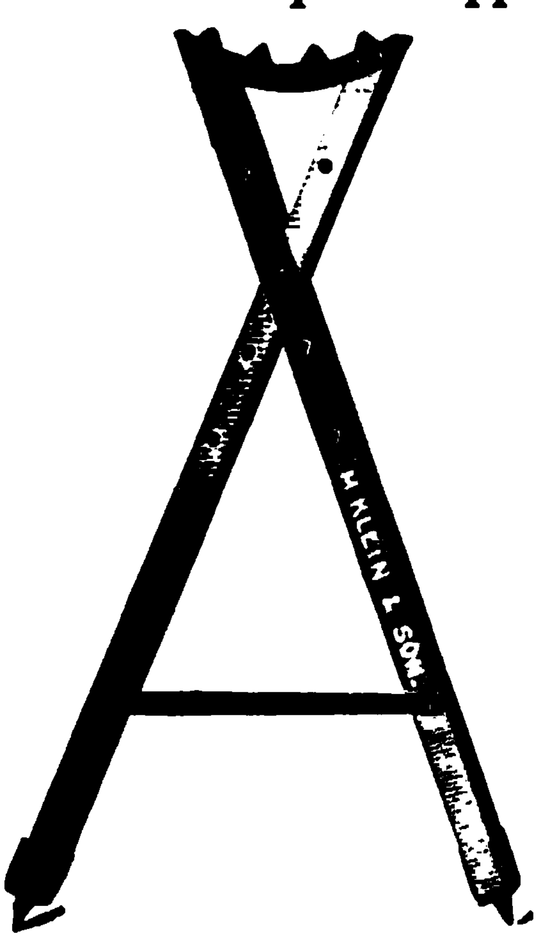


Fig. 69

73. The **cant hook,** Fig. 70, used for *rolling* or *turning* poles, consists of a maple or hickory handle about 4½ ft. long, to which a steel swing hook is pivoted at a point about one foot from the end. A ferrule provided with a steel spur, facing the point of the hook, is placed around the end of the handle.

74. The **peavy** is a tool similar to the cant hook, with the exception that the steel spur projects in line with the handle, instead of facing the hook.

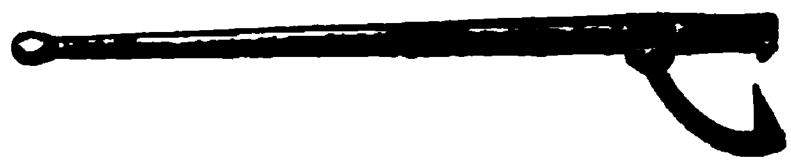


Fig. 70

Fig. 71

75. The **lifting** and **carrying hook,** Fig. 71, is used when poles have to be carried a short distance. The handle is from 4 to 7 ft. long. The hooks, which are sometimes provided with a swivel bearing at the point where they are attached to the handle, take hold of the pole as the handle is raised by two men.

76. Wood Working Tools: The tools used for such carpenter work as is required in preparing poles for cross-arms, etc., are a **hand cross-cut saw,** preferably a small one, **chisel, mallet, long bit** and **brace,** and **hatchet.*** A large **cross-cut saw,*** operated by two men, is usually required if poles must be sawn through in order to square the butts, or change the length.

77. Wire Stringing Tools: The following are some of the more important of the various tools and devices used for running and stretching wire.

78. Pay-out reels, Fig. 72, are used to support the coil of wire and allow it to turn, so that the wire may be unwound without kinking. Two of the upright iron rods are removable to allow the coil to be put into place.

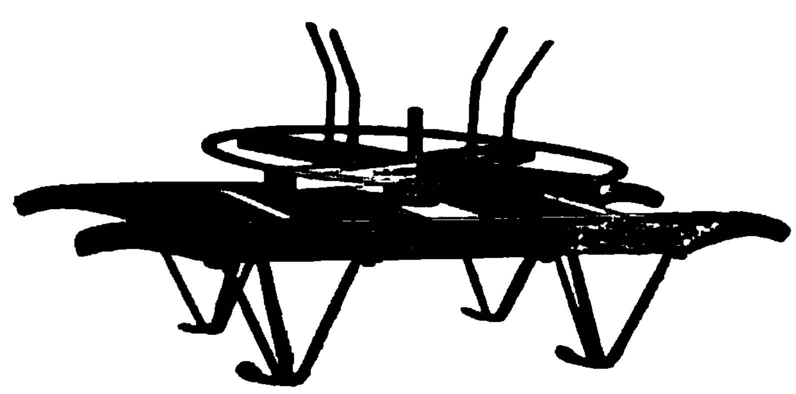


Fig. 72

The illustration shows the reel mounted on a *hand barrow,* so that it may be carried readily. *Carrying straps* running from the shoulders to the handles are sometimes used to aid in supporting the barrow. Various other forms of reels are employed, but the principle is the same in all.

79. The **running board,** Fig. 73, is a device sometimes used for stringing wires. It consists of a piece of tough timber about

*See Tools.

as long as a cross-arm, which is provided with holes as shown, about the same distance apart as the cross-arm pins, by means of which the

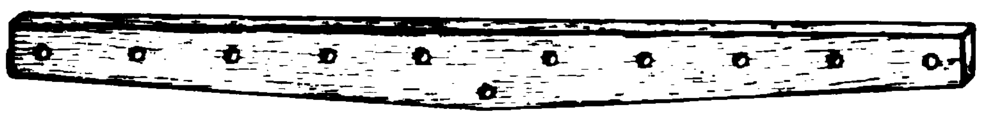


Fig. 73

wires may be attached. The running board is pulled from pole to pole drawing the wires after it by means of a rope running over the cross-arms and attached to the board at its center.

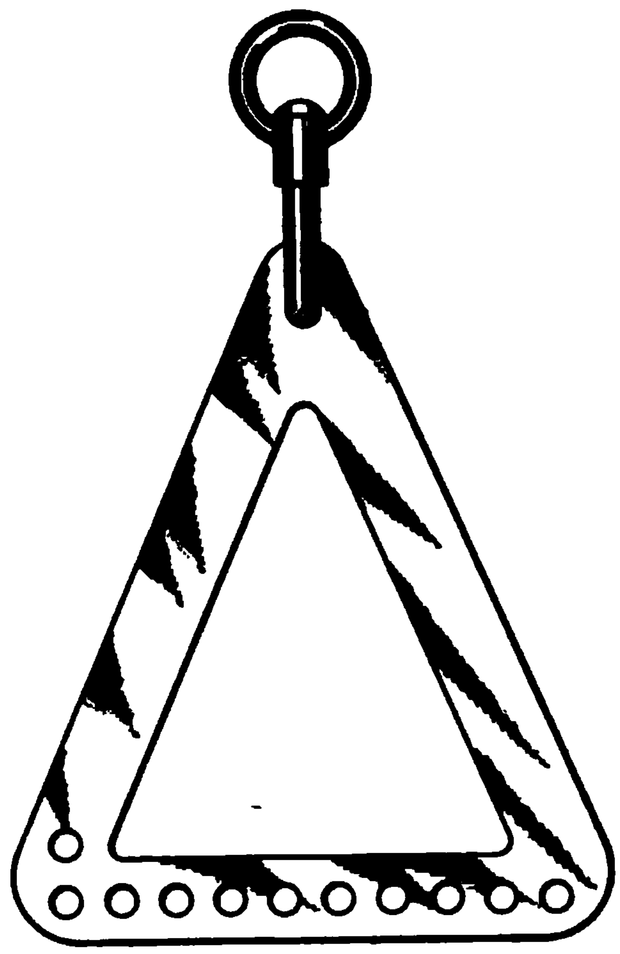


Fig. 74

The **line wire triangle,** Fig. 74, is a device made of steel and intended to serve the same purpose as the running board.

80. Come-alongs, Buffalo and other grips, wire clamps, stretchers, etc.,* are different tools for accomplishing the same purpose, that is gripping a wire so that it may be pulled to the proper tension, the Buffalo grip, Fig. 75, being an example. They are portable quick acting clamps, which may be easily attached to or released from a wire. In the best forms they do not nick or otherwise injure the wire or its insulation. The Buffalo grip is sometimes provided with curved jaws for use with insulated wire, thus providing a greater contact surface, and lessening the tendency to flatten the insulation.

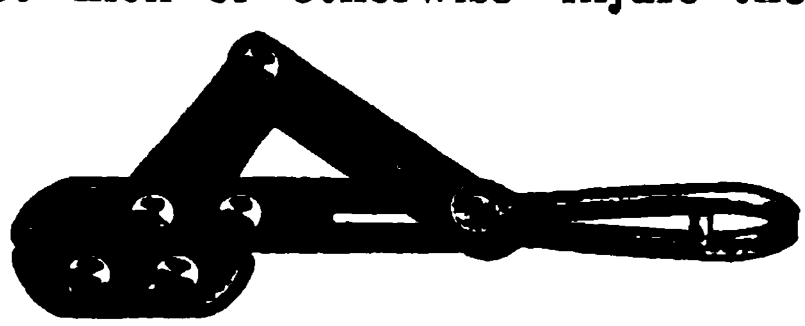


Fig. 75

81. For the purpose of applying the necessary tension, some form of tackle is ordinarily used, such as a pair of small tackle blocks,** Fig. 76, furnished with a suitable rope, usually ⅜ in., rove through the

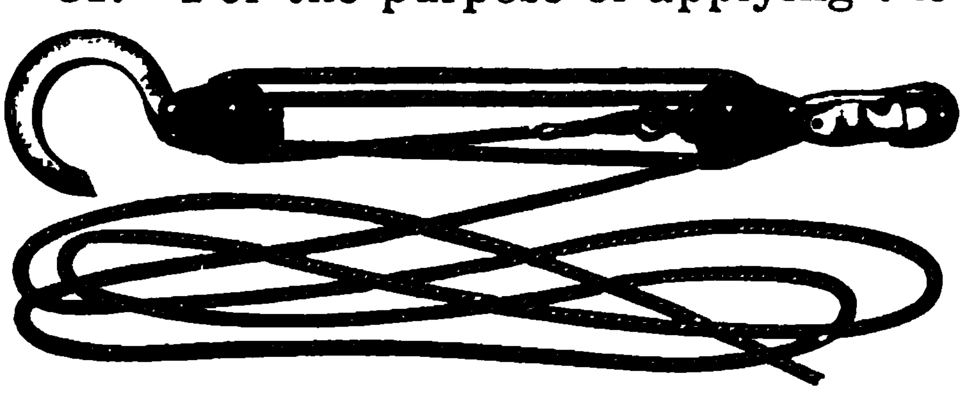


Fig. 76

*The term *come-along* is often applied in a general way to any tool of this type.
**See Tools.

pulleys, and provided with hooks by means of which they may be connected to a come-along and a support, such as an insulator pin placed in a cross-arm. This is called a **slack tackle.** Where wires extending in opposite directions are to be pulled up, two come-alongs, each fitted with a double pulley and connected together by a suitable rope, are frequently used.

82. A strap running over rollers, Fig. 77, is frequently used in place of rope tackle. The hook shown in this illustration is provided with a swivel, and is intended to be placed around an insulator pin when the tool is used. A catch is sometimes added to the tackle, so that when the proper tension has been obtained, the strap may be locked in position until released by the lineman. When fitted in this way the device is known as **Howe's wire tool.**

FIG. 77

83. The **lineman's** or **hand vise,** Fig. 78, is a convenient tool for obtaining a secure hold on a wire, and also for holding wires when making joints. It is often used with a strap, as shown in Fig. 79, to pull up wires, and is then known as a **strap vise.**

FIG. 78

FIG. 79

84. In case it is desired to measure the tension that is applied to a wire, a **line dynamometer,** Fig. 80, which is a form of spring balance, may be placed between the tackle and come-along.

FIG. 80

85. A **hand line** is simply a piece of good rope, usually ½ in. in diameter by about 75 ft. long.

86. *Block and tackle* for applying the proper tension to guy wires, etc., generally consists of two blocks with two or three sheaves each, joined by a ½ in. or ¾ in. rope, depending on the character of the work.

87. **Climbers** are made in two different styles known as **Eastern** climbers, Fig. 81, and **Western** climbers, Fig. 82. They are fastened to the legs with straps and are used in climbing poles, trees, etc. In use a hold is obtained by driving the spur into the wood with a downward thrust of the leg, the body being held out at arms length from the pole, which is clasped in the palm of the hands.

Eastern climbers are made in lengths of from 15 to 18 in. by ½ in. variations and Western climbers from 14 to 19 in. by ½ in. variations. The Eastern pattern should fit the foot so as not to strike the ankle, as otherwise it may throw the leg so that the spur will lose its hold.

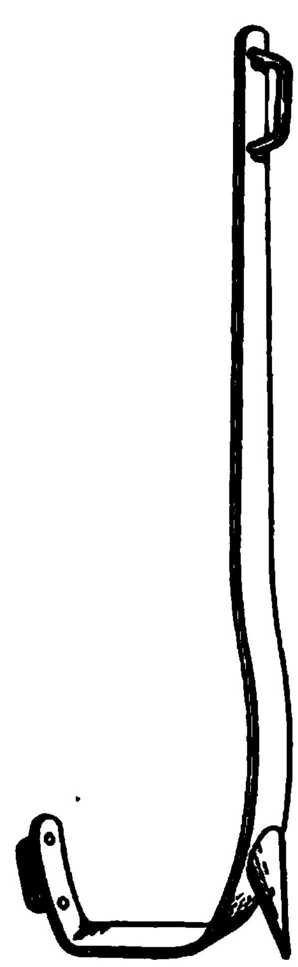


Fig. 81

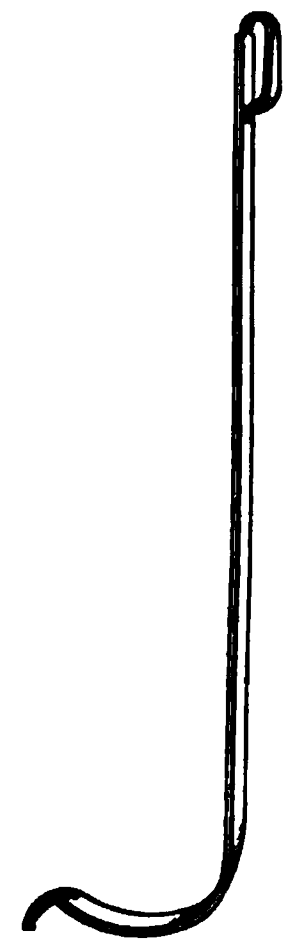


Fig. 82

88. Fig. 83 shows *straps* for the Eastern climbers and Fig. 84 those for the Western climbers. In the latter pattern the spur passes through the ring in the lower strap, which is also known as a *foot strap*. The lower straps are sometimes made with the buckles at an angle so as to fit the foot better. The up-

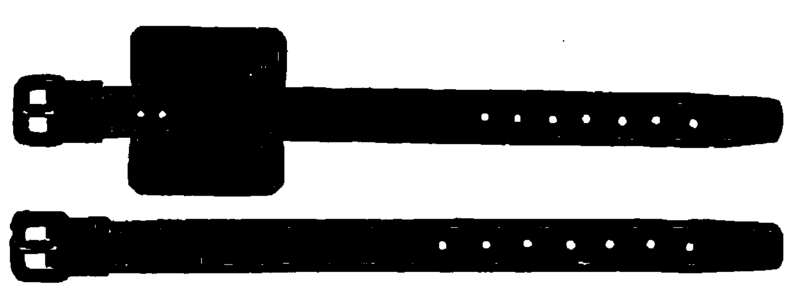


Fig 83

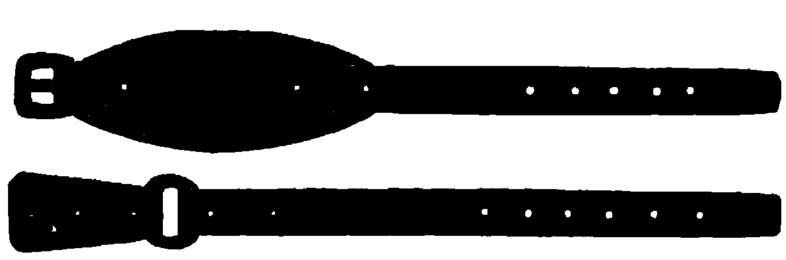


Fig. 84

per straps are provided with pads to protect the legs where the climbers bear against or pull on them.

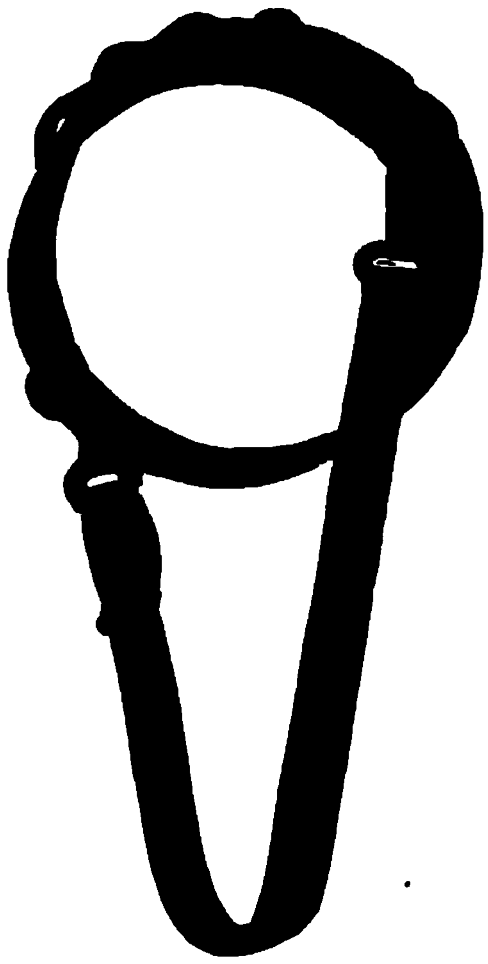


FIG. 85

89. The **lineman's belt** with the **safety strap**, Fig. 85, serves as a means of carrying tools, and aids in maintaining a position on a pole. The **plier pocket,** Fig. 86, slips on the belt and affords a convenient means of carrying pliers, while the **leather pouch,** Fig. 87, which also slips on the belt, is desirable for carrying screws and other small pieces.

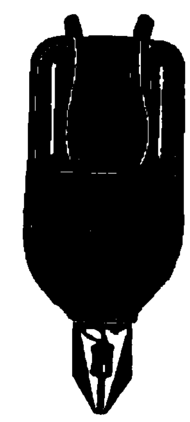


FIG. 86

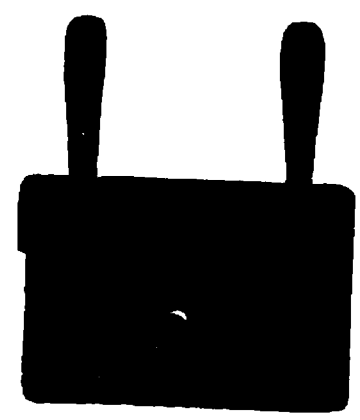


FIG. 87

90. Pliers* are used for holding and cutting wire and are made in various sizes from 5 to 10 in., the larger sizes being used on heavy wire. They are made with jaws of various shapes to adapt them to different kinds of work.

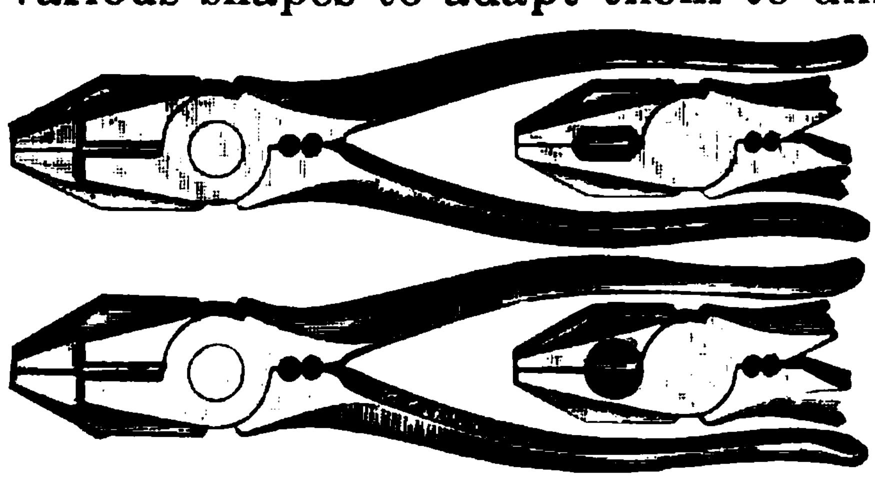


FIG. 88

Fig. 88 shows side cutting pliers which are provided with grooves in the handles near the joint so that they may be used to twist wire connectors. Plier handles are frequently insulated with mica or rubber to reduce the danger in working on live wires.

91. Splicing clamps, Fig. 89, are used for twisting *wire connectors*, one clamp being placed on one end of the connector and the pliers or splicing wrench, Art. 92, on the other end. They are made with different sized jaw open-

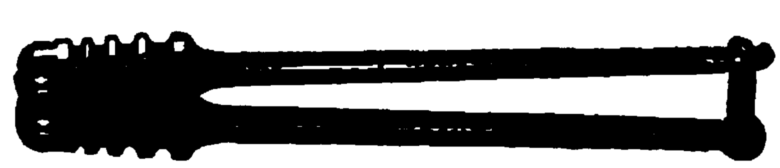


FIG. 89

*See Tools.

ings to accommodate connectors of different sizes. They are also made with jaw openings shaped to hold the wires in making a joint of the Western Union type.

Splicing clamps are made in two ways. In the style shown in the illustration *both* sides of the jaws are utilized, the hinge being arranged so that the handles may be swung around or reversed, to bring the outer grooves inside. In the other style only *one* side of the jaws is provided with grooves and the handles are not reversible.

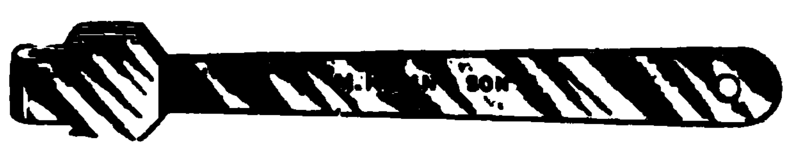


Fig. 90

92. **Splicing wrenches,** Fig 90, are used with the splicing clamp in making wire joints of the Western Union type. They are also made with openings, as shown in Fig. 91, so that they may be used in conjunction with the splicing clamp for twisting connectors.

Fig. 91

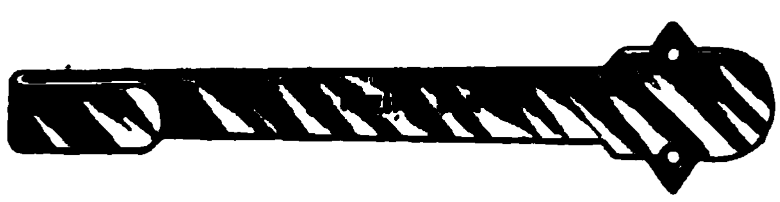


Fig. 92

93. **Tie wire wrenches,** Fig. 92, are used in coiling tie wires, at insulators, around the line wires.

94. The **electrician's knife,** Fig. 93, is a convenient tool for stripping off insulation, cleaning wire, etc.

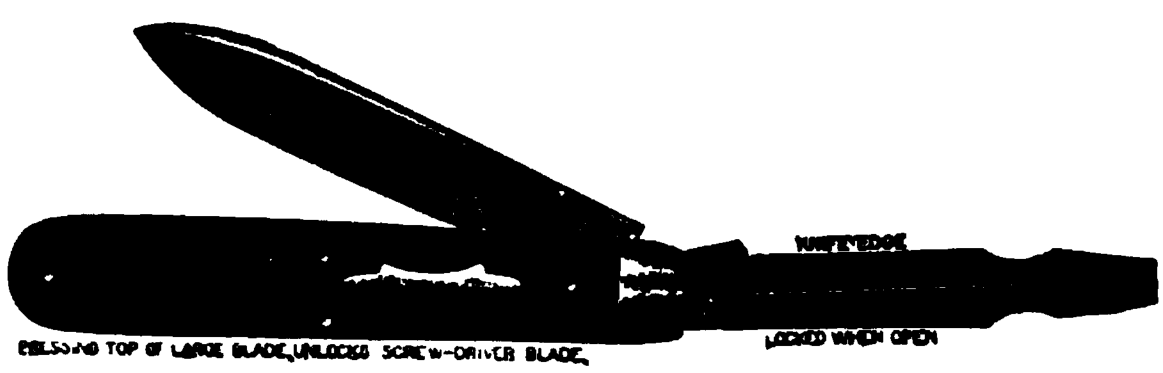


Fig. 93

Fig. 94

Another tool for stripping insulation from small wires is the **Perry wire-peeler** shown in Fig. 94.

95. Fig. 95 shows two styles of **lag screw wrenches.**

Fig. 95

96. Wire meters or **wire measuring machines,** Fig. 96, are convenient when it is necessary to measure large amounts of wire. The wire is passed between rollers in the meter, these being self adjusting to take wires of different sizes. The rollers drive the registering mechanism which indicates the number of feet that pass between them.

Fig. 96

97. Take-up Reels: When wire is taken down and is to be preserved,* it should be wound into a coil, which may be conveniently done by means of a *take-up reel,* Fig. 97. These are made in various sizes from 18 to 24 in., in diameter, and are constructed so that the guides on one side may be detached to allow the coil to be removed.

Fig. 97

98. The **tree trimmer,** Fig. 98, is a tool for conveniently reaching and cutting branches from trees. It is attached to the end of a pole and the branches are either cut with a knife by pulling a wire attached to the lever or if too large to fit into the hook, they are cut by means of the saw. The saw is usually detachable so that the trimmer may be used without it. Trimmers are also made without the saw attachment.

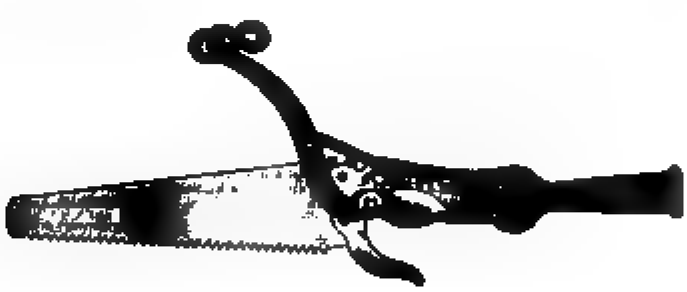


Fig 98

*Even if not to be preserved, it must be removed from the right of way and therefore is generally wound into coils so as to be easily handled.

INSTALLATION

99. Pole Line Diagrams: These are drawings whose purpose is to furnish the necessary information to linemen, as to how to run the wires when lines are being constructed. They also assist maintainers, after the lines have been constructed, in tracing circuits and locating faults. They are especially useful where a large number of wires, or complicated circuits are employed.

100. Pole line diagrams are made up from circuit plans, and in many instances are made a part of them. When separate, and also, if necessary, when part of the same drawing, the wires are given the same numbers or letters, as those appearing on the circuit plans, so that corresponding wires may be easily identified.

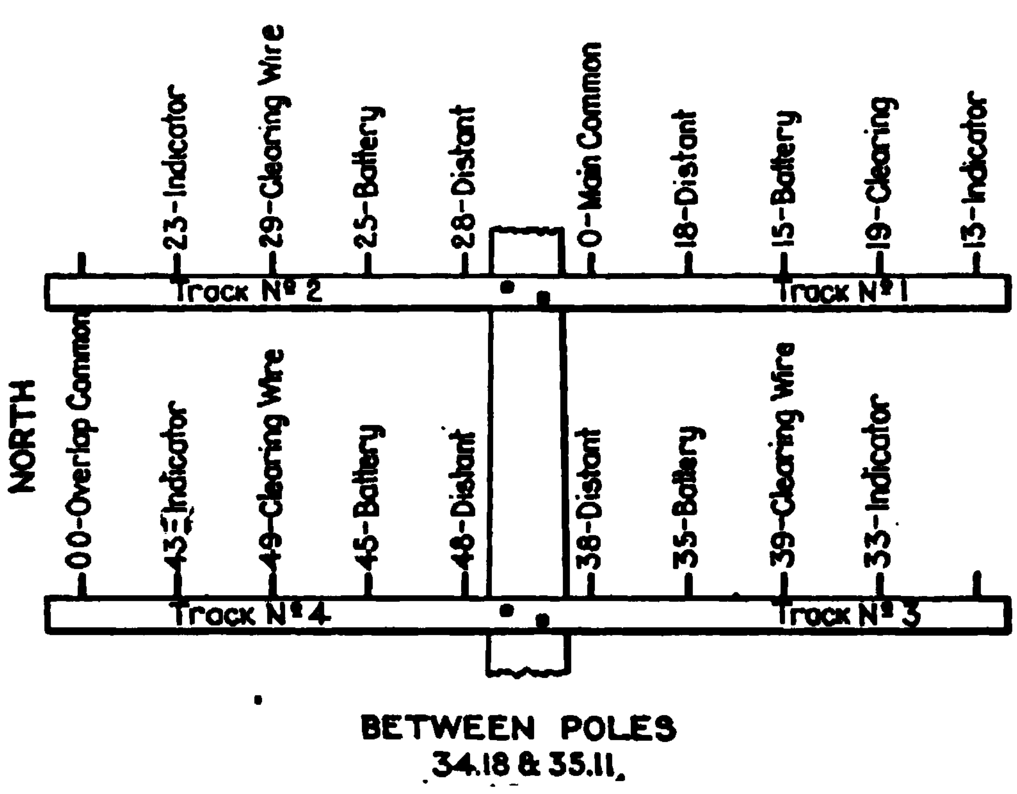


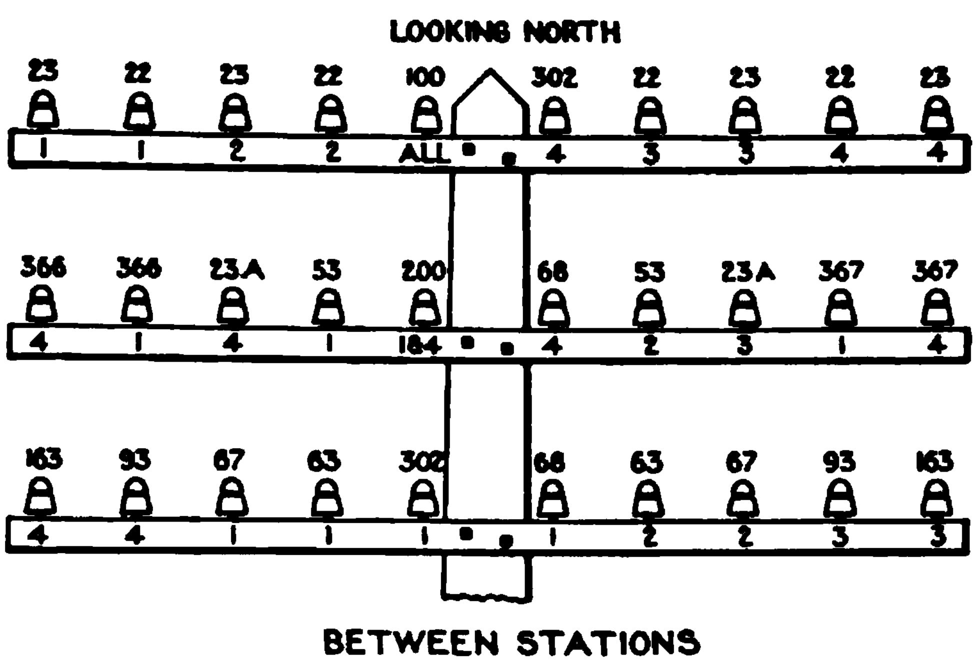
Fig. 99

101. There are a number of different ways of making pole line diagrams. In one of these, as illustrated in Figs. 99 and 100, a view of a pole top is given, and the position of each wire shown. In Fig. 99 the *function* performed by each wire is noted above it, as well as the *wire number*, while in Fig. 100 the same information is given in a table. In some instances, where no system of wire numbering is in use, the function is, of course, all that can be given.

102. The word "NORTH", appearing at the left, Fig. 99, shows that the general direction of the line is *east* and *west*, and that the view is taken from the *west* side of the pole. In Fig. 100, similar information is conveyed by the words "LOOKING NORTH", which indicate that the general direction of the line is *north* and *south* and that the view is taken from the *south* side of the pole.

103. Pole Numbering. The notation at the bottom of Fig.

99 represents a system of numbering poles, commonly used to indicate the location to which a diagram applies, and which is employed to a considerable extent by telegraph companies, on whose poles the signal wires are frequently placed. The *mile-posts* form the basis of this system. The pole number is divided into *two* parts, either by a *decimal point* as shown, or by a *dash*; the mile-post number being given first and then the number of the pole, counting from the mile-post. For example, if the starting point of the mile-posts is at the easterly end of the road, pole No. 34.18 would be the 18th pole west of the 34th mile-post. It is customary to have the pole number painted on every fifth pole in black figures upon a white background, the figures being arranged vertically and a horizontal line separating the two parts of the number.



Nº	FUNCTION
22	Distant signal control
23	Home " "
23A	" " " at overlap
53	Approach indicator
63	Rear block repeater
67	Distant repeater
68	Bell outlying switch
93	Advance block signal control
100	50 Volt common
163	Advance block repeater
200	10 Volt common
302	Switch approach indicator
366	Outlying switch release
367	" " lock

Fig. 100

104. Other systems of numbering are of course available, especially on short lines. For instance, beginning at one end of the line, the poles may be numbered consecutively; or beginning at the tower of an interlocking plant, making the junction pole at the tower O, they may be numbered consecutively from it in all directions, as N-1, N-2, etc., on a line running north, and E-1, E-2, etc., on a line running east.

105. Another method of giving the locations on pole line diagrams, is by the use of *chaining stations*, as shown in Fig. 100.

Other means of designating the location to which the diagram applies are sometimes satisfactory, such as *Between Sig. 5.7 and Sig. 6.4** or *Between Towers DA and FY.*

*Automatic block signals are usually numbered, as will be described later in **D. C. Block Signaling.**

FIG. 101

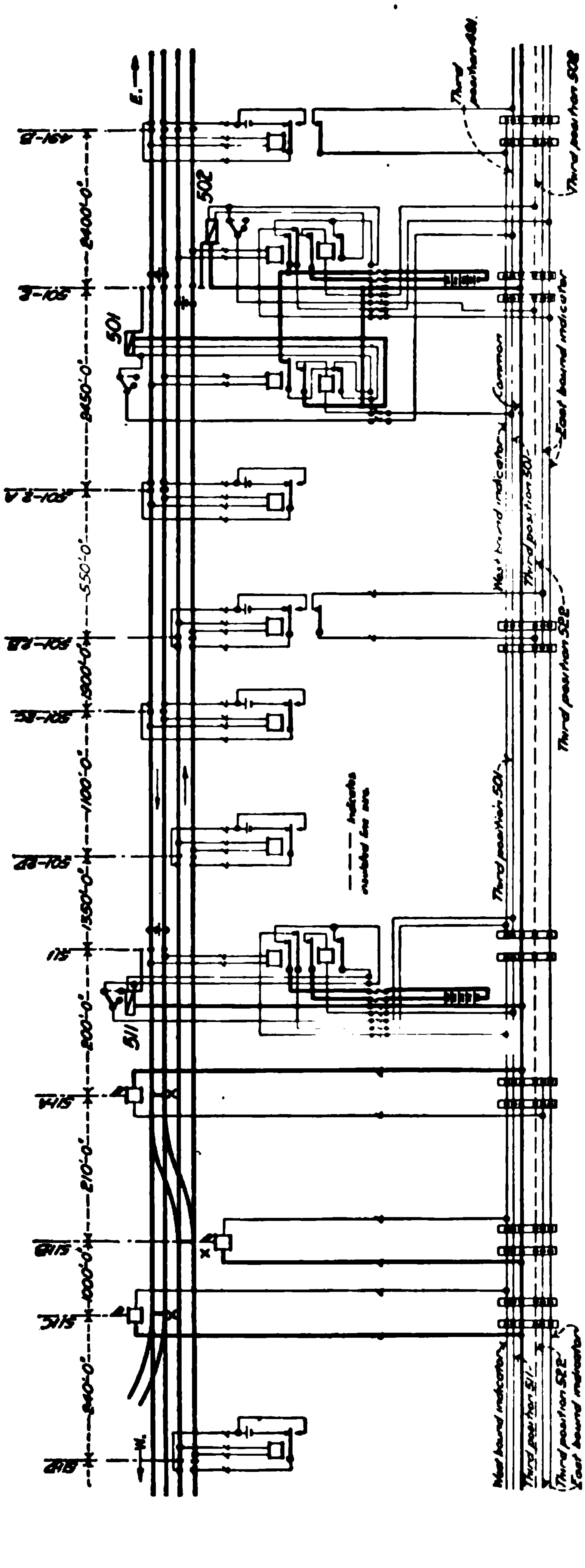


Fig. 102

106. The method just described, of making pole-line diagrams, is especially satisfactory when the wires maintain the same positions on a number of successive poles. When any of the wires change their position in the line, another diagram is made. In some instances a collection of these diagrams, covering a certain length of the line, are arranged in their proper order to form a small book. Diagrams of this kind are in some cases drawn along side the wiring on circuit plans.

107. Fig. 101 illustrates another method of making pole line diagrams. This diagram is made in the form of a plan or map of the wires and cross-arms, at poles where the wires change their positions. The wire designa-

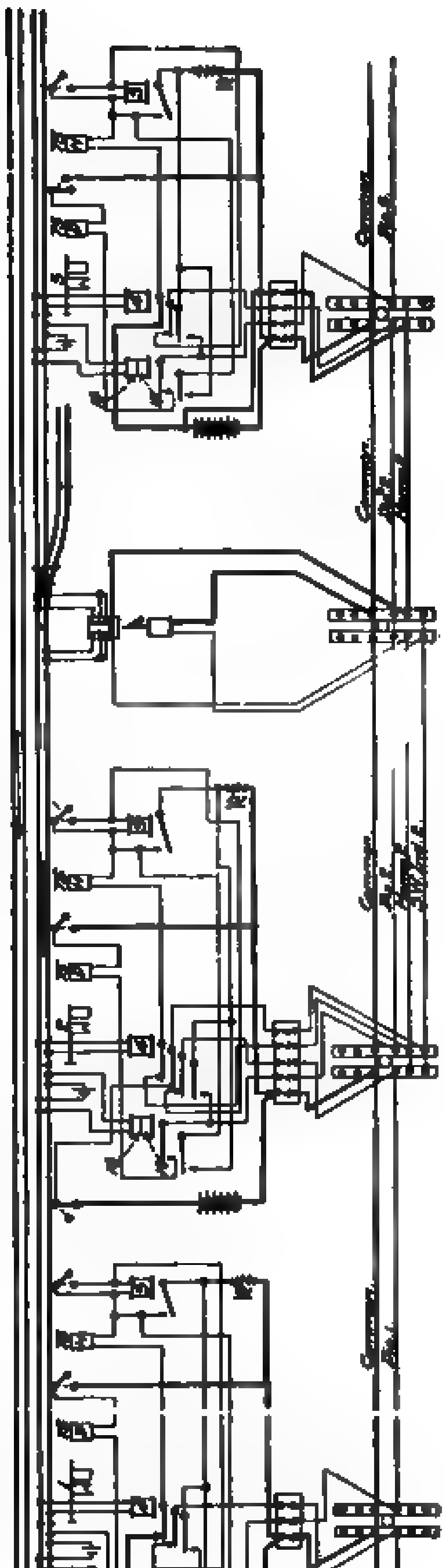


FIG. 103

FIG. 104

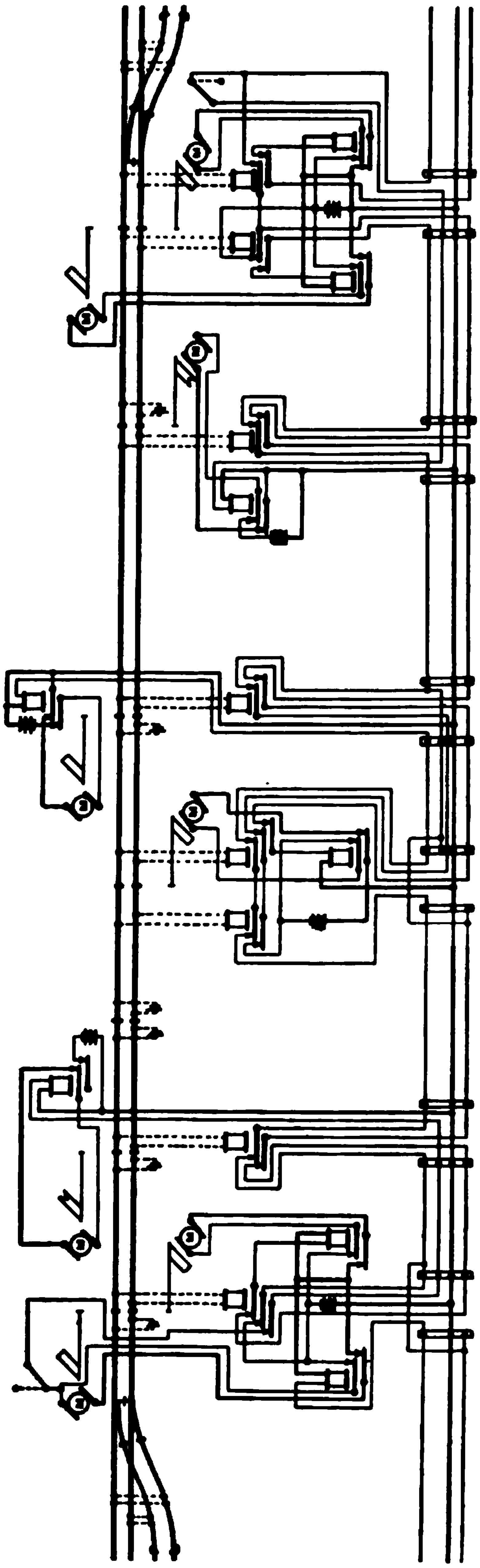


Fig. 105

tions appear above the wires, and the size of each wire is given at its ends.

108. Diagrams of this type are sometimes drawn on the same sheet as circuit plans, the method of combining them being illustrated in Figs. 102-105. In these illustrations, the cross-arms at each change or break in the line are indicated. In Figs. 102 and 104, the leads from the line to the instruments are drawn at the most convenient points, although these may be some distance from the cross-arms. This does not show where these connections are actually made, but merely indicates to which wires the leads are attached, connections being made at the pole. In Fig. 103, the leads are carried out obliquely from the insulators; while in Fig. 105, the double cross-arms are drawn sufficiently far apart to allow the leads to be carried out between them.

109. In diagrams of the type illustrated in Figs. 101-105, the pole locations may be given opposite each pole. This is in many instances unnecessary,

however, as the location is made sufficiently clear by the positions of buildings, such as towers, crossing cabins, stations, etc.; or switches, signals, etc.

The principal dimensions, Fig. 102, sometimes appear on the plans and in some cases the mile posts are given, thus conveying information regarding locations.

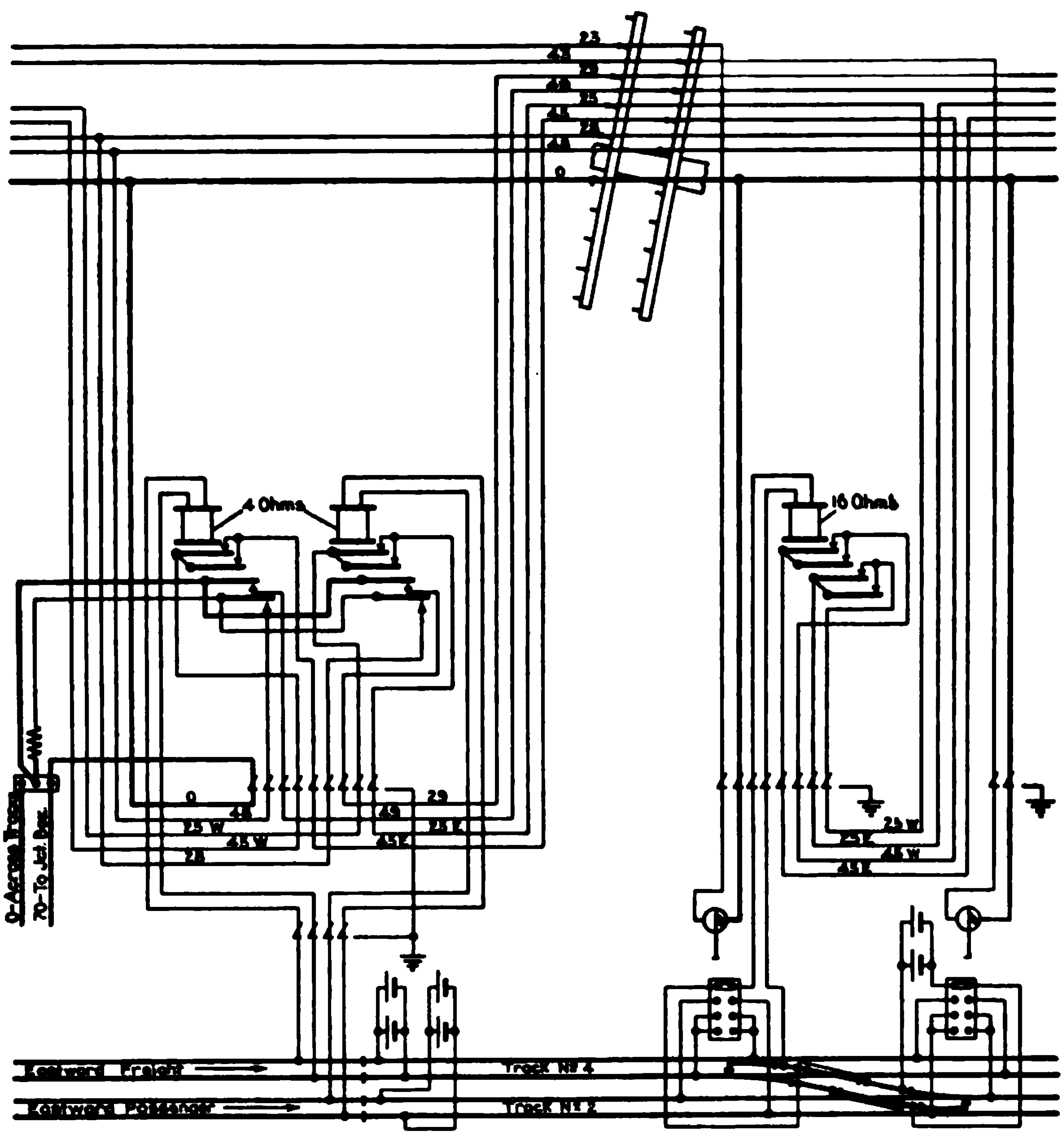


Fig. 106

110. Another type of pole line diagram, which may be considered a combination of the two types already described, is illustrated in Fig. 106. In this method an intermediate pole top, between the points where changes in the line occur, is drawn with the cross-arms at such an angle, that, as the wires cross them, they will touch their proper insulators.

111. When making up pole line diagrams it is desirable to first fill the spaces on the *upper* arms, the spare pins or spaces being left on the *lower* arms for future use. When determining the position of the wires on the arms, they should if possible be balanced, that is, as much weight placed on one side of the pole as on the other. This applies principally to the lower arms, when left with spare spaces.

112. Location of Line: In many cases signal wires are run on telegraph poles, which have already been located along a railroad. It is occasionally necessary, however, to erect a line separate from the telegraph line. Such a line should be as short and straight as practical, the poles, of course, being placed on railroad property where possible. It is desirable that the wires should be visible from passing trains, so that their general condition may be observed when riding over the railroad. The line should cross the track as few times as possible, and guys across the tracks, highways, etc., should be avoided.

113. It is generally desirable to run the line parallel with the track, setting the poles at a uniform distance from the nearest rail. Usually there is a standard minimum distance, which governs the space between the poles and the track. This in one case is 10 ft. from the center line of the track to the center of the pole. Care should be taken to keep the ends of the cross-arms a sufficient distance outside of the minimum clearance line, to prevent their causing injury to trainmen. When it is undesirable to increase the height of the line, this may be accomplished by the use of side arms.

114. If it is necessary to run a line over property which does not belong to the railroad company, suitable rights of way must be obtained. These should include permission to erect the required poles, guy stubs, and guys; to make necessary attachments to buildings or other property; to string wires; and to trim interfering trees and shrubbery, as may be essential to the proper working of the line.

115. Spacing and Distributing Poles: Before starting on the erection of poles, the location of each pole is determined by measurement and located by a stake, the space between poles being

according to requirements. Stakes may also be driven to locate the proper position of guys or braces.

116. In locating poles, when the line cannot be run parallel with the track, it will be found of assistance to place two long stakes at a considerable distance apart, along the line to be followed, and then to drive the stakes indicating pole positions in line between the long stakes. Stakes at pole positions are marked with the height of the pole and, if the pole is to be guyed, this fact may be indicated, and also whether an anchor hole or stub hole is to be dug.

117. On straight sections it is considered good practice to locate the poles at equal distances of about 176 ft., which corresponds to 30 poles per mile, when the number of wires in the line does not exceed *six*. This space is reduced to 132 ft., corresponding to 40 poles per mile, when more than six wires are used. When the number of wires will never exceed two, spaces of about 264 ft., or 20 poles per mile, may be used. The distances are measured off without regard to obstacles, the poles being located as near the stakes as possible.

118. On *curves* and *corners* the number and location of the poles should be such as to secure the proper strength. The following table gives some data for various lines:

	Span** in Feet	
Amount of Pull* in Feet	**Bracket or 6 Wire Line†**	**Heavier Lines**
1 to 4	176	130
5 to 9	165	120
10 to 14	150	110
15 to 19	135	100
20 to 24	120	90
25 and over	100	75

119. Whenever the pull, Fig. 107, on a one pole corner would be more than 25 ft., the corner should be made on *two* poles, as shown in Fig. 108 at B.

*See Fig. 107.
**Distance between poles.
†A line having one six pin cross-arm on each pole.

120. At *line terminals*, with a bracket or six wire line, the last span at the end of the line should not be over 100 ft., and for heavier lines not over 75 ft.

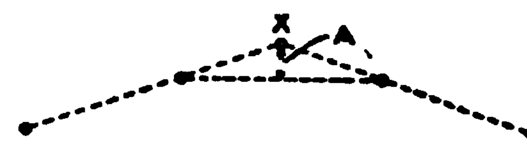


FIG. 107

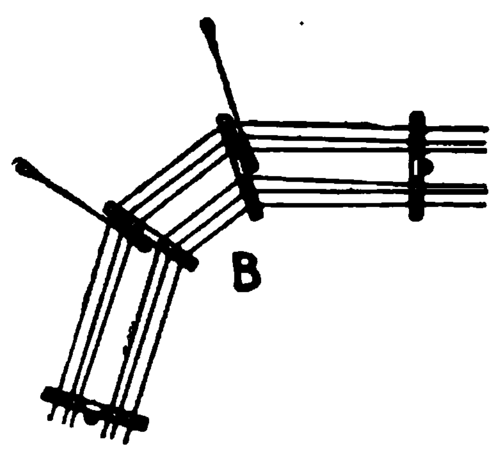


FIG. 108

121. When it is necessary to use a *long span*, as in crossing a river, if the distance is 250 ft. or over for a bracket or six wire line, or 200 ft. or over for a heavier line, the span on each side of the long span should not be over 100 ft., or 75 ft. respectively.

122. In distributing the poles, those that are heaviest and most substantial are placed at corners, curves, terminals, and long spans, and the longest poles are used in depressions, and the shortest on elevations, so as to compensate as far as possible for changes in the level of the ground.

In general *short* poles should be used, the minimum height being determined by the clearance required between the lowest wires and the ground, which should be at least 12 ft., and by the number of cross-arms. Long poles should be employed only to clear obstacles, and avoid abrupt changes in the level of the line. Wires should clear obstacles by at least 2 ft., and preferably 4 ft.

123. When lines run above or across railroads, highways, buildings, etc., it is necessary to have a specified clearance. Various railroad companies have different standards for this clearance, which is generally at least 22 ft. between the lowest point of the line and the tops of the rails. In the case of highways, it is customary to require that the lowest point of any line shall be at least 18 ft. above the highway or sidewalk.

When lines cross buildings, the National Board of Fire Underwriters specify that the wires be at least 7 ft. above the highest points of flat roofs, and at least one foot above the ridges of pitched roofs, over which they pass or to which they are attached.

124. Digging Holes: Holes for poles should be large enough in diameter, so that the pole may be placed in position without hewing, and should be full size at the bottom, to permit the use

of an iron tamping bar after the pole is in position. The depth of the hole is governed by the height of the pole, the following table giving the depths ordinarily used.

Length of Pole Feet	Depth in Ground, Feet	Depth in Solid Rock, Feet
18	3 on straight lines $3\frac{1}{2}$ on corners	3
20	4	3
22	4	3
[illegible]	5	3
30	$5\frac{1}{2}$	$3\frac{1}{2}$
35	6	4
40	6	4
[illegible]	$6\frac{1}{2}$	$4\frac{1}{2}$
50	7	$4\frac{1}{2}$

125. Holes are usually dug by loosening the ground with a digging bar, and removing it with a shovel or digging spoon. Certain kinds of soil, free from stones and not too hard, allow the use of the post hole auger, by means of which holes may be dug very rapidly. In rock and frozen ground, it may be necessary to break up the material to be removed by the use of dynamite.* This should be done, however, only by an experienced person. Holes which have to be left open over night or for a longer period should be covered, if necessary, to prevent accidents.

126. Gaining and Trimming Poles: Before poles are erected they are cut or provided with *gains* to receive the cross-arms, as shown in Fig. 109, and the necessary holes bored for bolts, $\frac{11}{16}$ in. holes being considered good practice for $\frac{5}{8}$ in. bolts and $\frac{9}{16}$ in. holes for $\frac{1}{2}$ in. bolts. Gains should be cut true and square, so that cross-arms will fit accurately, stand at right angles to the poles, and line up with one another, the last requirement being obtained by placing straight edges in the gains and sighting from one to the other. Care should be taken to cut the gains so that any bend in the pole will show

Fig. 109

*See Concrete.

least, when viewed in the direction of the line. The depth of gains should not be greater than ½ in. when braces are used and generally should not exceed 1¼ in.

127. All bark and soft wood is carefully removed from the pole, knots trimmed closely and smoothly, butts squared, and the top roofed,* if that work has not been done previously. Finally the roof and each gain is given from one to three coats of white lead, or other paint suitable for this purpose. If a bolt hole is bored in a gain at which an arm is not to be attached, the inside of the hole should be given a coat of paint.

128. Ringing: This is accomplished by shaving the top of the pole so that the ring may be driven into place, 1 in. below the base of the roof. The ring is then secured by four six-penny galvanized wire nails, driven directly above it and spaced equally.

129. In some cases the top of the pole is left flat instead of being roofed, so that it may be equipped with an insulator pin, Fig. 110, a pole ring being placed around the top of the pole to prevent it from splitting.

Fig. 110

130. Ground Wires: When this form of protection is used one pole in a certain number, for example varying from every pole to every tenth pole, should be equipped, before it is erected, with a ground wire. This may serve in addition as a lightning rod. No. 6 B. W. G. galvanized iron wire is suitable for this purpose, and is attached to the pole with 2 in. galvanized iron staples, spaced 2 ft. apart. It should extend the entire length of the pole and to produce a better ground should be provided at the bottom with two turns, placed so that they will come underneath the butt when the pole is in position; or the ground wire may be connected to a ground rod or plate, after the pole is erected. To serve as a lightning rod the wire is extended at least 12 in. above the top of the pole, and is often sharpened to a point. Ground wires should be as straight as possible and there

*The term *sniped* is also used.

should be no turns or coils throughout their length, as such turns or coils would oppose a high inductive reactance to high frequency currents, such as lightning discharges.*

131. Pole Steps: Pole steps are used principally on terminal, junction, and other poles which it may be necessary to climb frequently. Their use is desirable on such poles to prevent them from being roughed up, as the frequent use of climbers may cut the surface of the pole to such an extent that it is difficult and unsafe to climb.

132. If pole steps are required they are placed in position before the pole is erected. They may be placed either parallel with the cross-arms, or at right angles to them as shown in Fig. 2. The steps should be staggered, the spacing center to center of steps varying, according to the diameter of the pole and local practice, 18 in. on centers being considered good practice. If galvanized iron pole steps are to be used, holes four inches deep and considerably smaller than the thread may be bored for their reception, or the steps may be simply driven and screwed into place. Wooden pole steps, which are often made by cutting off the ends of brackets, are fastened with one sixty-penny and one forty-penny galvanized wire nail.

133. Cross-Arms and Fittings: Previous to erecting the poles the brackets or cross-arms are distributed, the latter being fully equipped with braces and pins before distribution, if wooden pins are used. In case steel pins are used, they are not placed until the line wires are strung.

134. After the pole line is erected, regular pins are replaced with transposition pins wherever necessary. Each pin is nailed in the cross-arm with one six-penny galvanized wire nail, driven in straight from the middle of the side of the arm.

135. Attaching Brackets and Cross-arms: If a pole is to have only brackets, or one or two cross-arms, the brackets, and sometimes the cross-arms, are generally attached *before* the pole is erected. Cross-arms are liable to be troublesome, however, especially if there is not much space and only a small number of men to aid in erecting. If a pole is to have several arms, one

*See Magnetism and Electricity.

of them may be attached before the pole is erected, but if all are put in place it usuall y makes the top too heavy to raise.

136. *Brackets* are ordinarily attached to the pole by one sixty-penny and one forty-penny galvanized wire nail as shown in Fig. 111. Sometimes a thirty-penny nail is used in place of the forty-penny nail. On curves and corners, where the direction of the line changes, both brackets are placed on the outside of the curve, one above the other, as in Fig. 112. In some cases, if it is desired to place one or two more wires on a pole, and all the cross-arms are full, brackets are attached as shown in Fig. 113.

Fig. 111

Fig. 112

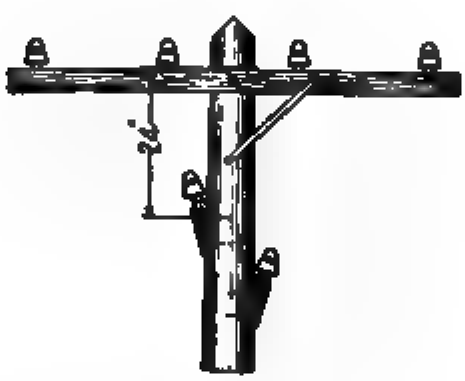


Fig. 113

137. When a cross-arm is attached to the pole by one ⅝ in. center bolt, the bolt should be long enough to go through the pole and cross-arm, without cutting out the back of the pole. The bolt is driven in from the back of the pole. When two ½ in. lag screws are used instead of the center bolt, they are placed as shown in Fig. 114. Two ½ in. bolts may be used in place of the lag screws. Large washers should be used under heads and nuts in all cases.

138. *Cross-arm Braces.* In attaching braces to cross-arms a ½ x 1½ in. round washer is placed under the head of each bolt, and the bolt driven into the cross-arm from the side that is to come next to the pole, so

Fig. 114

that the washer may rest in contact with the cross-arm.

139. Braces are not generally used on two pin arms. *One* brace is often used instead of *two* on a four pin arm, while arms having more than four pins are usually provided with at least *two* braces.

140. Braces are attached to poles as described in Art. 29. On *corner* poles equipped with ten pin cross-arms, where the pull is 12 ft. or more, or where a line is exposed to severe strains, *back braces* should be used in addition to the regular braces, and in some cases *double arming braces.*

141. *Double Arming.* At bad corners and other places where the strain on the cross-arms is severe, and in many cases where leads are carried from the line to signal devices, double arming, Fig. 20, should be used. Each of the arms is braced the same as a single cross-arm, although in some cases only one arm is braced. In place of *double arming*, the *double arming* or *back brace*, Fig. 19, is sometimes used.

142. *Alley Arms.* These are fastened in practically the same manner as regular arms. The vertical brace is bolted to each cross-arm and the diagonal brace attached to the pole either with a lag screw or bolt and to the lower cross-arm with the same bolt as is used for the vertical brace.

143. Erecting Poles: Before raising the pole it is moved to a favorable position with its butt over the hole. Then an oak plank or two digging bars are placed in the hole, on the side farthest from the pole, to form a guide and prevent the earth from being displaced by the butt in its descent.

144. The small end of the pole is then raised by hand and supported by the dead man, until the men change their position so as to raise it higher. When the pole is again lifted the dead man is moved toward the butt, being held inclined slightly toward the butt in order to always push the pole toward the hole. This process is continued until the top of the pole is high enough to allow the use of pike poles, the men then working as nearly under the pole as possible, but spreading slightly to prevent it from falling sideways. As the pole is raised the pike poles are shifted one at a time to a position nearer the butt, this opera-

tion being continued until the butt slides into place. The dead man should be always kept in position to take the load.

145. The raising of poles may be accomplished much more quickly by means of some form of tackle, or a movable derrick. Methods for raising poles by tackle, which may be used in line construction, will be described later in *Mechanical Interlocking.*

146. After the pole is raised it is turned until the cross-arms or gains are at right angles to the direction of the line, brought to the required upright position, and steadied by three or four pike poles with their ends firmly planted in the ground, while the earth is filled in around it.

147. The position of all poles on straight lines should be vertical, while those on curves should *incline* slightly *outward,* so that the tension of the wires will tend to pull them toward a vertical position. If the pole is out of line less than 5 ft. the amount of *incline* or *rake* should be about 10 in., from 5 to 10 ft. about 15 in., and when over 10 ft. about 25 in.

148. Facing of Cross-arms. On *straight lines* the cross-arms on adjacent poles should face in *opposite* directions, since if the cross-arms all faced one way, the pull of the wires, in the case of one pole breaking, would be liable to tear the cross-arms off the other poles. On a *long span* the cross-arms should face *away* from the span. At *line terminals,* if not double armed, those on the *last two poles* should face *outward.* On *single pole corners,* those on the *corner pole* should face *away* from the longer straight section, and those on the *first* pole in *each* direction should face *toward* the corner pole. On *curves* they should *all* face toward the middle of the curve. At *diagonal crossings,* they should be placed on the sides of the poles *facing* the crossing.

149. *Filling and Tamping.* Only one shovel should be used in filling the hole, two or three tampers being employed continuously at the same time, to thoroughly ram the earth in place around the pole throughout the entire depth of the hole. After the hole is completely filled in this manner, the earth is banked up for a distance of about 1 ft. and firmly packed around the pole. This aids drainage by causing surface water to run away from the pole. In filling, the coarse soil or gravel should be placed at the top of the hole.

150. *Pole Foundations.* The preceding method applies when the earth is firm. When the soil is sandy, or quicksand, swamp, or bog is encountered, other methods must be employed to secure a sufficiently firm foundation. In all of these cases the holes should be dug wider and at least 1 ft. deeper than usual. In sandy soil it is customary to use the so-called *sand barrel.* A strong barrel with both heads removed is placed in the hole, and the pole set inside of it and braced in the proper upright position with the pike poles. In very weak soil, which runs into the hole as fast as it is removed, the barrel is placed on the surface and the soil dug away inside of it, the barrel being pushed down as the digging progresses to prevent the soil from running in. The space around the barrel and between the barrel and the pole is now tamped full of clay, or other firm, substantial soil. By this means a larger bearing surface is produced.

151. A *temporary sand barrel,* consisting of a special iron cylinder made in two halves, may be used in place of the wooden barrel, and hoisted out after the hole has been filled. This is sometimes called a *caisson.*

152. A still better foundation is constructed by filling in the space around the pole with *concrete,* consisting of one part cement, two parts of sand, and five parts of broken stone or coarse gravel. When this method is used an 8 in. layer of concrete should be placed on the bottom of the hole, for the pole to rest on, a pair of crossed planks being fastened to the butt as shown in Fig. 115.

153. In moist and boggy soil the space around the pole may be filled with broken rock well tamped down, and the rock piled around the pole for at least 2 ft. above the surface of the ground; or a ground brace formed of logs 4 to 6 ft. long may be bolted to the pole butt, as shown in Fig. 18.

FIG. 115

154. Other methods for use in very boggy places, consist of building a platform on the surface, or a combination of a *platform* and *piles.* These are illustrated in Figs. 116 and 117.

Poles set in sandy bogs should be *pointed* at the lower end in order to stand well. Otherwise, due to the vibration caused by

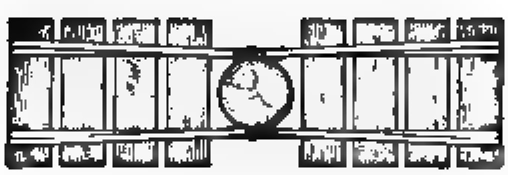


Fig. 116

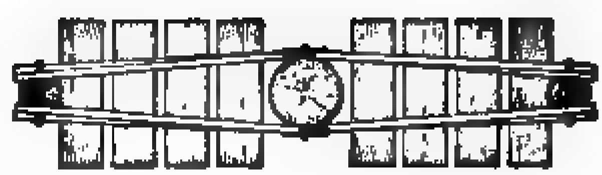


Fig. 117

the wind, the sand works under the butt and gradually lifts the pole.

155. When rock is encountered, the proper hole may be blasted, and the space between the pole and the sides of the hole filled with broken stone, firmly wedged in place; or a 1½ in. hole may be drilled and an iron pin, which will protrude 6 in., placed in it, this pin fitting a hole in the butt of the pole. The butt may be provided with a pole ring to prevent it from splitting. The pole is then braced sideways by guys or by three or four wooden struts, spiked to the pole at a point about 6 ft. above the ground, and running diagonally to the rock, to which they are securely attached.

156. Construction at Bridges: On trestle work or on bridges, the supporting structure of which is entirely or largely below the deck, poles may be attached and braced to the bridge as shown in Fig. 118. If only a single arm is required, it may be

Fig. 118

bolted to a timber extending horizontally from the bridge deck. If the deck of the bridge is not too far above the ground or river bottom, the butts of the poles may be set in the ground, and the poles attached to the bridge on a level with the bridge deck by heavy iron straps, sometimes in the form of large U bolts. When the latter construction is used the poles should generally be placed opposite piers, so as to be protected by them.

When the supporting structure of the bridge extends *above* the bridge deck, the cross-arms may be bolted, or clamped and braced directly to the bridge members, no poles being used; or poles, usually square, may be bolted to the bridge. However, on account of the many different types of bridges, the construc-

tion in each case will usually be determined by the existing conditions.

157. Attaching Cross-arms to Standing Poles: If all the cross-arms were not attached to the pole before it was erected, they should be put on after it is firmly set. If the top cross-arm was attached before the the pole was raised, the next cross-arm is conveniently hoisted up with a rope, by a lineman seated on the top arm. After the cross-arms are in position, and before the bolts are tightened, they should be lined up one at a time with the other arms on the pole, by sighting from one to the other. As soon as each one is parallel with the arms already fixed, all bolts are tightened.

158. As most signal wires are run on telegraph poles, more work will probably be done on these poles than on new poles. To produce a neat appearance, arms of the *same* length and with the pins *spaced the same* as those on the telegraph cross-arms should be used. In attaching cross-arms for signal wires to telegraph poles, a spare gain is usually left between the telegraph and signal cross-arms, to allow the telegraph company to string additional wires without moving the signal cross-arms.

EXAMINATION QUESTIONS

(1) (*a*) What is the usual top circumference of poles employed for lines having more than six wires? (*b*) For what purpose are guys used? (*c*) Name two devices which may be used to fasten a guy at the earth end.

(2) (*a*) What is a cross-arm? (*b*) What is a side arm? (*c*) What is a cross-arm brace?

(3) (*a*) Why are insulators used? (*b*) How are the insulators attached to the cross-arms? (*c*) What device is used in case it is desired to support one insulator from the side of a pole?

(4) (*a*) Name three devices used for carrying wires from one position to another along the cross-arm. (*b*) Why are wire guards used?

(5) What are wire connectors?

(6) (*a*) Draw a diagram showing how a lightning arrester may be connected to the line and to the earth. (*b*) Name two devices that may be used to make the ground connection.

(7) (*a*) What is friction tape? (*b*) What is rubber tape?

(8) (*a*) What are tools known as come-alongs used for? (*b*) What are splicing clamps used for?

(9) What information does a pole line diagram furnish to a lineman?

(10) (*a*) What is meant by the term gaining as applied to poles? (*b*) Draw a sketch showing how a pole is ordinarily roofed.

(11) Make a sketch showing how a six pin cross-arm is attached to a pole.

(12) What is meant by the term double arming?

(13) (*a*) How should cross-arms face on a straight line? (*b*) How should cross-arms face on a curved line?

(14) What is a sand barrel used for?

159. To resist stresses that tend to bend or pull out the poles, such as the tension of wires at corners, curves, and terminal poles, **guys** and **braces** are used.

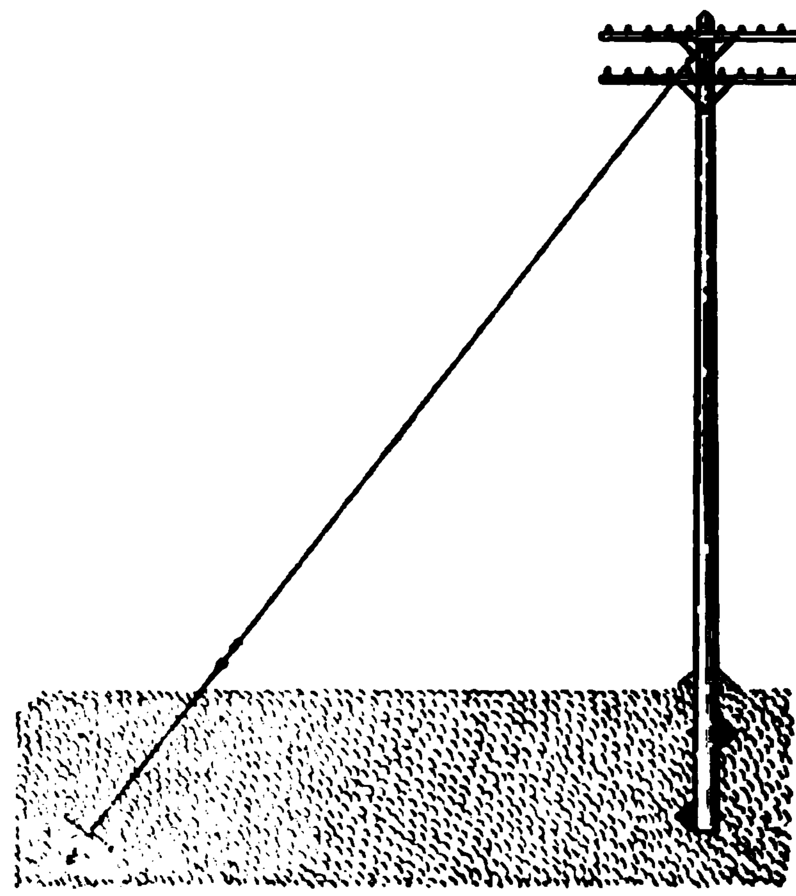


Fig. 119

160. Guying: Light lines, such as bracket and six wire lines, are often guyed with No. 8 or 6 B. W. G. galvanized steel or iron wire. Heavier lines are generally guyed with galvanized stranded steel wire, varying from $\frac{1}{4}$ to $\frac{1}{2}$ in. in diameter depending upon the strain to which it is subjected.

161. For one or two cross-arms the method of guying shown in Fig. 119 is satisfactory. When there are several cross-arms, however, the method known as *Y guying*, shown in Fig. 120, is probably the best, as it has less tendency to bend the pole than other methods.

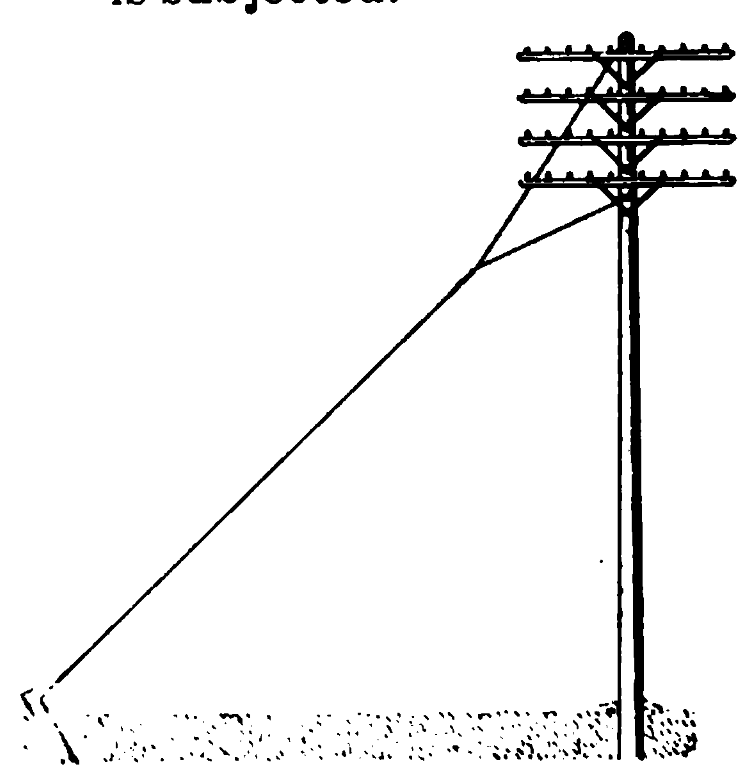


Fig. 120

162. For a line with two wires guys are seldom needed, except at terminals and on corner poles where the angle from a straight line is 45 deg. or more, and at road crossings.

163. For a six wire line, all poles on which the pull (Fig. 107) is more than 15 ft. should be guyed.

If the line carries between six and twelve wires, all poles on which the *pull* is more than 5 ft. should be either guyed or reinforced at the butt as shown in Fig. 119, while all poles on which the *pull* is 10 ft. or more should be guyed.

If the line carries more than twelve wires, all poles on which the *pull* is more than 18 in. should be guyed.

Poles carrying alley arms should always be guyed if possible.

164. Whenever the line makes a right angle corner, or one that is nearly a right angle,

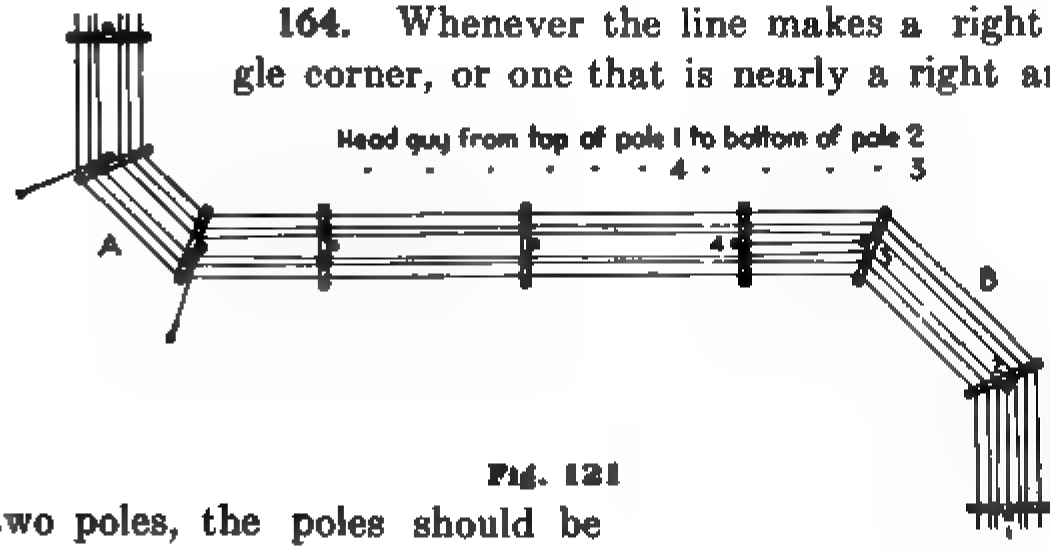


Fig. 121

on two poles, the poles should be guyed as shown at A, Fig. 121. The method of arranging the arms and guys when it is impossible to side guy

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single guys in the positions indicated by the dotted lines

Fig. 122

are generally sufficient.

166. *Head guying* consists in guying the top of one pole to the butt of the next, Fig. 123, or to an anchor, and is used to provide additional strength against stresses in the direction of the line. A similar method of guying for the same purpose is

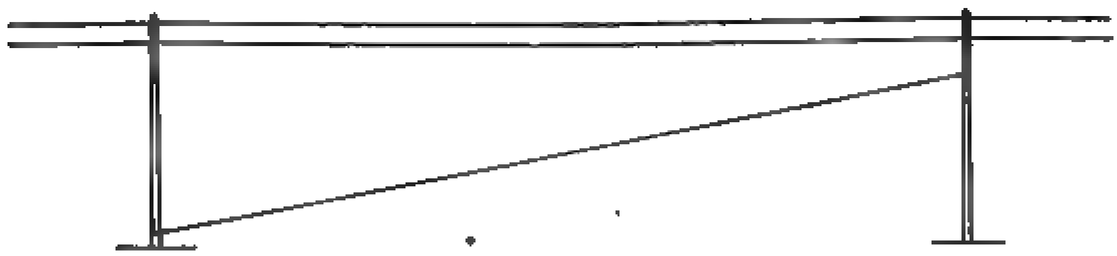


Fig. 123

known as *double guying*, or *double head guying*, Fig. 124.

167. The poles of a line carrying more than six wires should

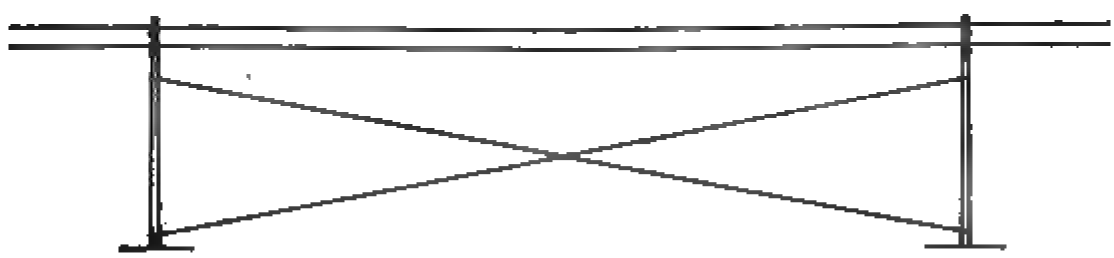


Fig. 124

be head guyed at the end of every span of 200 ft. or more and if possible guyed on each side at right angles to the direction of the line. When such a line is dead ended the pole adjacent to the terminal pole should be head guyed.

168. In hilly country a line having more than six wires should be head guyed to take the downward strain, as shown in Fig. 125.

Fig. 125

169. *Storm Guys*. If a line has twenty wires or more, in addition to the guying already specified, head guys should be

used at crossings, or corners where the pull is 25 ft. or more, and there is a long straight section next to the corner. These are known as storm guys, their purpose being to prevent the entire line or long sections of it, from going down in case the wires are broken at one point by a storm or otherwise.

170. The preceding directions for guying cover only standard conditions. In case of swampy ground, light sand, or where pole settings are insecure, more guys than described should be used.

Guys are generally installed before the wires are run as it is easier to pull them up. They may be insulated, if necessary, by inserting suitable strain insulators at the proper points.

171. Placing Anchors and Stubs: In locating anchors, the distance from the butt of the pole to the anchor should not be less than one-fifth the length of the pole, and should preferably be about equal to the length of the pole.

172. Excavations for anchor logs should usually be at least $4\frac{1}{2}$ ft. deep. If impracticable to obtain this depth, on account of the nature of the ground, the depth of excavation should not be less than $3\frac{1}{2}$ ft. The size of the anchor log depends upon the depth of excavation. If the excavation is 5 ft. deep, it is considered good practice to use a log 5 ft. long, and at least 8 in. in diameter. For shallower excavation the length and diameter of the log should be increased somewhat. In place of the

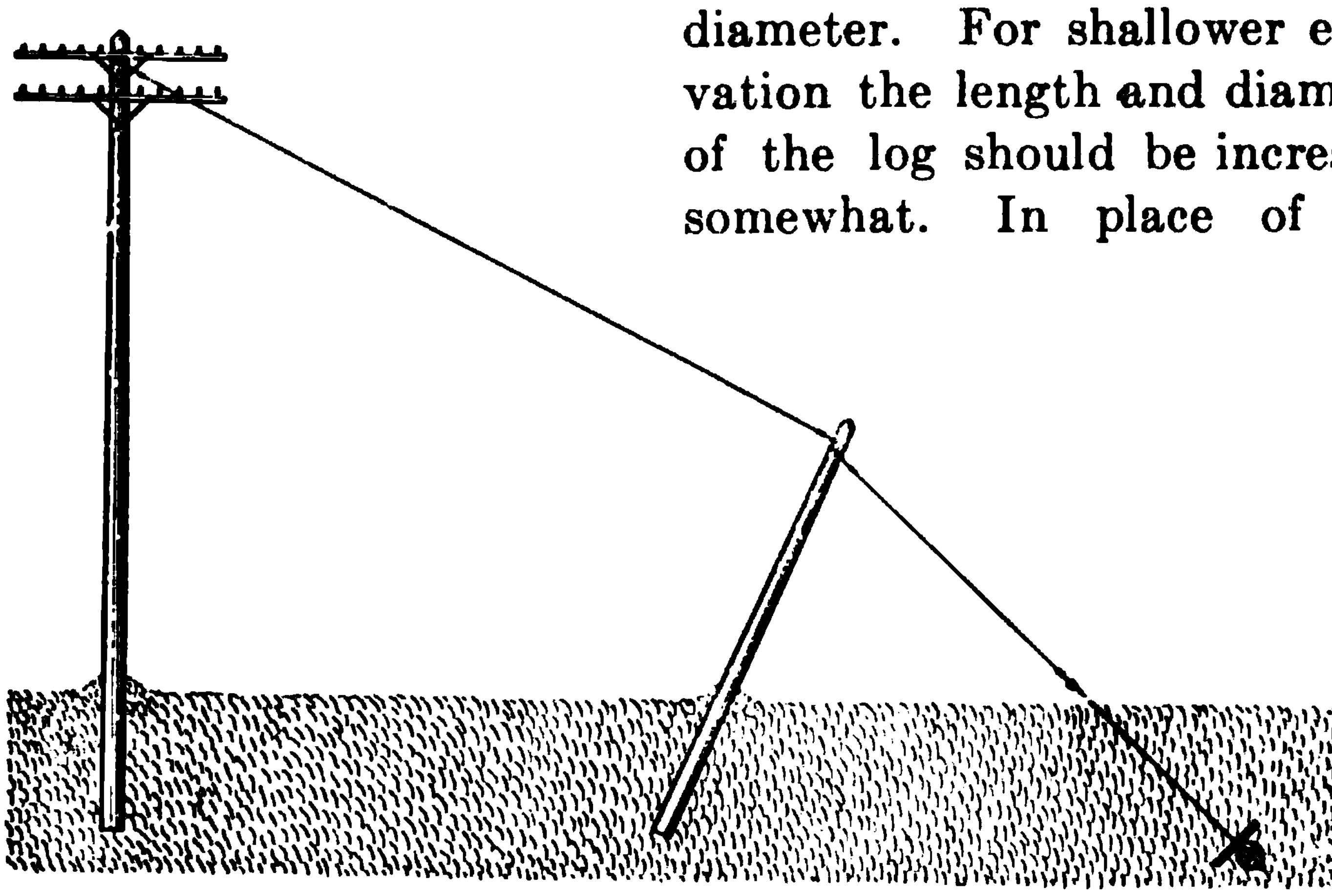


FIG. 126

methods of anchoring employing logs or other anchors buried in the earth, guys are often fastened to short stubs as shown

in Fig. 120. If stones are available they may be piled around anchor logs and stubs before tamping in the earth, to render them more secure.

173. *Long guy stubs,* Fig. 126, are used only when it is necessary to raise guys over roadways, or to clear obstacles. They should have a top circumference of at least 18¾ in., and are generally made from crooked poles. The top should be pointed to an angle of 60 deg. and given one or two coats of suitable paint.

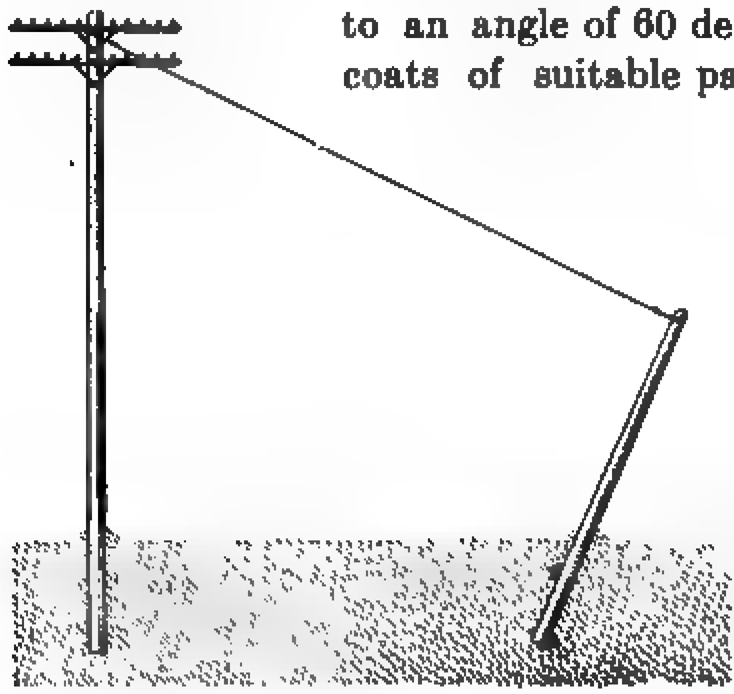


Fig. 127

174. Each stub should be set in the ground to a depth of at least 5 ft., and should be inclined so as to lean away from the pole as shown in Figs. 126 and 127. In case it is impossible to anchor the guy stub, **ground braces** may be used as shown in Fig. 127.

175. Attaching Guys: When brackets or not more

Fig. 128

Fig. 129

than two cross-arms are used, guys should be attached to the pole below the lower bracket or upper cross-arm, in the manner shown in Fig. 119. Head guys are attached just below the lower cross-arm. When *solid wire* is used, guys are fastened at each end by *wrapping*, as shown in Fig. 131. When *stranded wire* is used, it is fastened at each end by means of *guy clamps* Fig. 128, or *wire rope clips*, or it may be fastened by a form of eye splice as shown in Fig. 129. A *thimble* is employed, Figs. 7 and 131, in attaching a guy to a guy rod, eye bolt, or turn-buckle.

The end of a guy attached to a pole or stub should be wrapped twice around, Fig. 129, and the wrapping held in place on the back of the pole or stub by 2 in. *staples*, or by means of a *guy hook*, as shown. To prevent the guy from cutting into the wood a heavy sheet of galvanized iron may be placed around the pole between the guy and the wood.

176. Guying to Trees: Guys may be fastened to suitable trees, Fig. 130, provided the right of way permits, although in general they are to be avoided as they are usually swayed more or less by the wind and the motion tends to weaken the line. The guy should preferably be attached to the tree trunk. In exceptional cases it may be attached to a live limb close to the trunk, providing the limb has a diameter exceeding 5 in.

Fig. 130

The trunk or limb of the tree must be protected from injury by being covered with strips of hard wood, and to prevent the tree from being strangled, the guy is looped only once around it. Light guys may be attached to trees, by fastening them to a drive or lag screw driven into the side of the tree furthest from the pole. Special care should be taken not to injure shade trees.

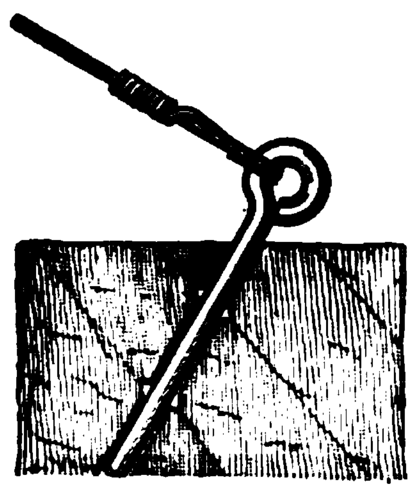


Fig. 131

177. Guying to Rock: When the rock is solid the guy may be anchored by a rock bolt, as shown in Fig. 5. This is fastened in place by drilling a taper hole in the rock, and expanding the shank of the bolt into the hole. When the rock is not firm and is likely to split off, the guy should be anchored as shown in Fig. 131. The length of the bolt will be determined by the nature of the rock.

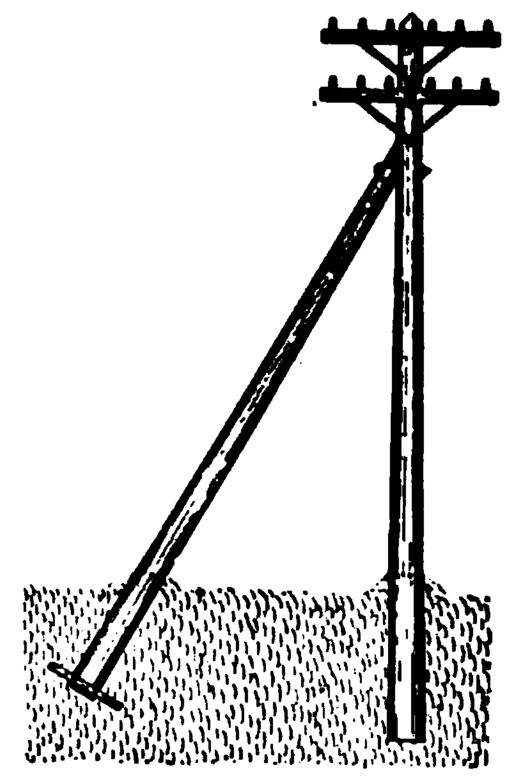


Fig. 132

178. A *ground brace*, as shown in Fig. 119, may be used under some conditions as a substitute for a guy, and to reinforce poles in soft ground.

179. Pole Braces: Pole braces are considered a secondary type of reinforcement, and are used only when conditions will not permit the use of guys. Guys are preferable to braces among other reasons on account of the fact that braces tend to raise the pole out of the ground. Braces are usually made from short poles, and are placed and fastened as shown in Fig. 132. The butt of the brace should be set at least 3½ ft. in the ground, and should be supported on a plank, large stone, or solid ledge of rock.

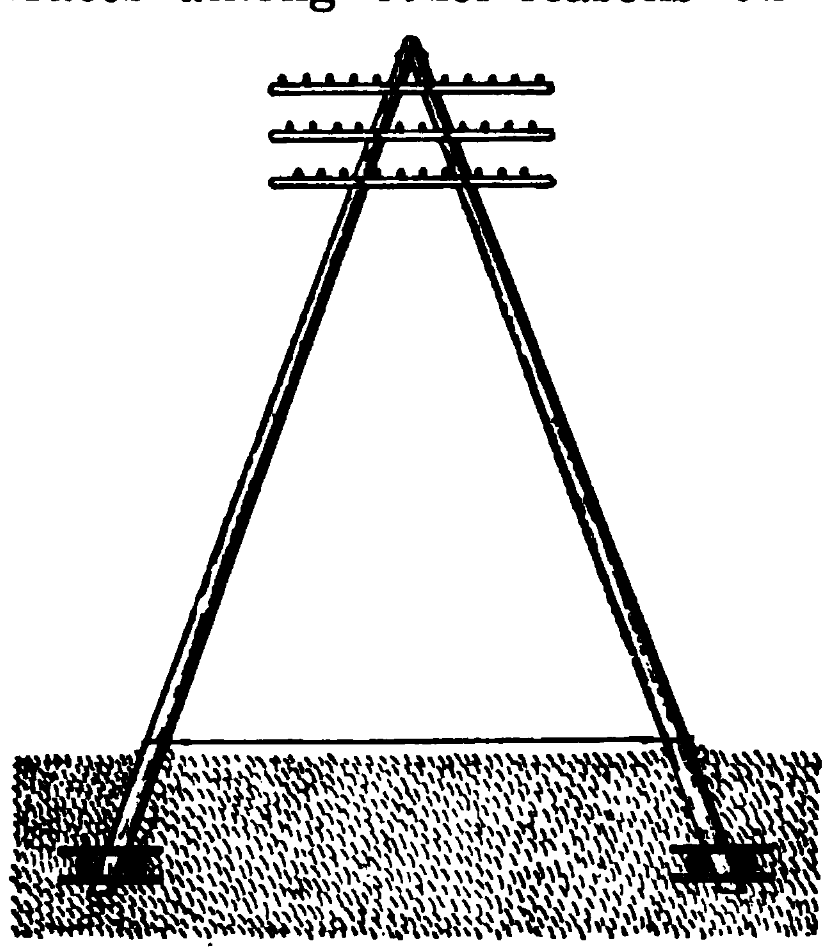


Fig. 133

180. When a line requires to be very strongly supported, double poles of the form shown in Fig. 133 may be used.

181. Stringing Wires: When only one wire is to be strung at a time, it may be fastened temporarily or *snubbed* at the pole at the beginning of the stretch, and then unreeled from a pay-out reel, carried along the ground near the poles. The wire is then taken up to each cross-arm, pulled to the proper tension, and tied to the insulators, which have previously been screwed tightly onto their pins. To prevent malicious interference the insulators are not usually put onto the pins, however, until everything is in readiness for stringing the wire. This same method may also be used for a small number of wires. In uncoiling the wire from the reel, care must be taken that it does not become kinked, as its strength is greatly impaired thereby.

182. If a coil of wire is to be paid out and no reel is at hand, the coil may be carried and the wire paid from off the outside, the coil being turned around after about five turns have been taken off, and back again after five more have been taken off, and so on. This process prevents the wire from twisting and kinking as it would be likely to do otherwise.

183. When one wire is strung at a time, the first wires should be placed on the two pins nearest the pole, one on each side, the other wires being added alternately on opposite sides of the pole.

184. Generally when several wires are to be strung the *running board* or *triangle* is used. In this method the coils of wire to be strung are placed on reels at the first pole of the stretch, and each of the wires threaded through a hole in the board and made fast. A rope that has previously been passed over all the cross-arms in the stretch, which is generally 1,500 to 2,000 ft. long, is fastened to the center of the running board, and the board lifted over the first cross-arm, after which it is pulled from pole to pole, a lineman stationed at each pole lifting the board over the arm and also guiding the wires. As soon as the running board has reached the last cross-arm over which the running rope passes, the wires are temporarily secured. This process is repeated until the line is completely strung.

In cases where wires are to be strung on other than the top

cross-arm, one side may be strung at a time, or the wires unhooked from the running board and passed around the pole.

185. In running insulated wire care should be taken to avoid abrasion of the covering, by drawing the wire over sharp corners or otherwise. As a rope can often be passed over other wires and where it would be unsafe to attempt to carry up a wire, it is frequently more satisfactory than carrying the coil, when stringing a small number of wires and even a single wire, to pull the wires into place with a running board, or simply with a rope in case of a single wire.

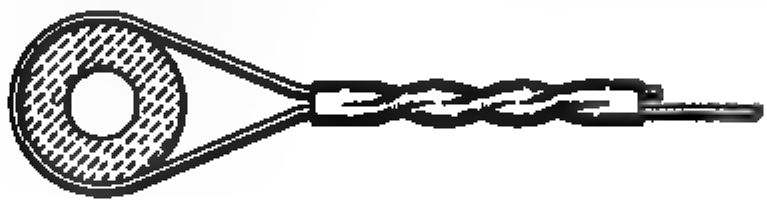


Fig. 134

186. Dead Ending: After the wires have been run out they are fastened at one end; then stretched, tied, and fastened at the other end. The term *dead end* refers to the fastenings at the ends of the wire.

Under some conditions there may be more or heavier wires dead ended on one side of a cross-arm than on the other. This produces a strain that tends to turn the cross-arm from its proper position at right angles to the direction of the line. To prevent the arm from turning, a guy or stay may be run from its end to the next pole, care being taken to locate the guy so that it will not interfere with the line wires.

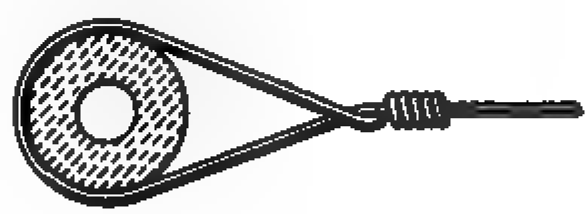


Fig. 135

187. The following are a few of the many methods that are used for dead ending wires.

Fig. 134 shows a simple form of dead end used in some cases

Fig. 136

for bare copper wire. It is made by pushing the end

Fig. 137

of the wire through one side of a half sleeve connector,

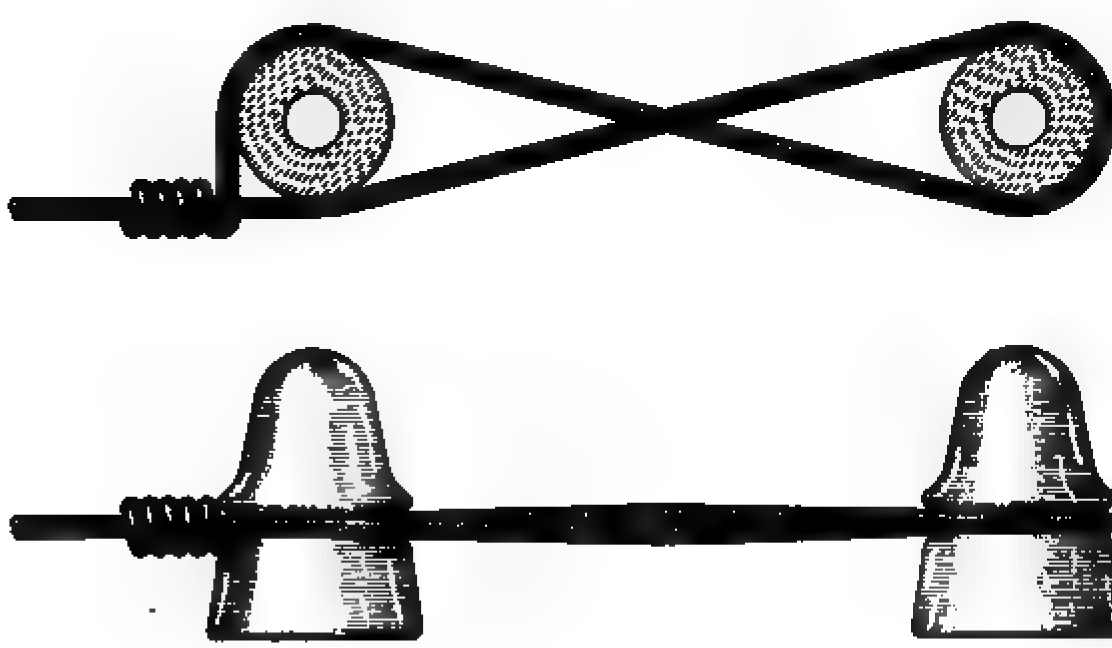


Fig. 138

then bending it around the insulator and pushing it through the other side. The connector is then given one and one-half turns, leaving the eye opening about 2 in. Bare iron and steel wires may be dead ended as shown in Fig. 135, being fastened with at least five full turns*. With either of these methods an additional turn is often taken around the insulator in order to make the dead end more secure.

Fig. 136 shows a method of dead ending insulated wire on two insulators, when double-cross-arms are used.

Fig. 139

It will be noted that the wire is wrapped twice around the terminal insulator. In some cases, to make the work es-

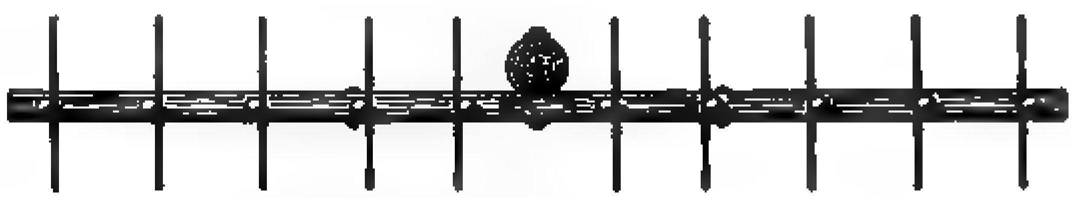


Fig. 140

pecially secure, it is also wrapped once around the other insulator as shown, in addition to the regular tie. Other meth-

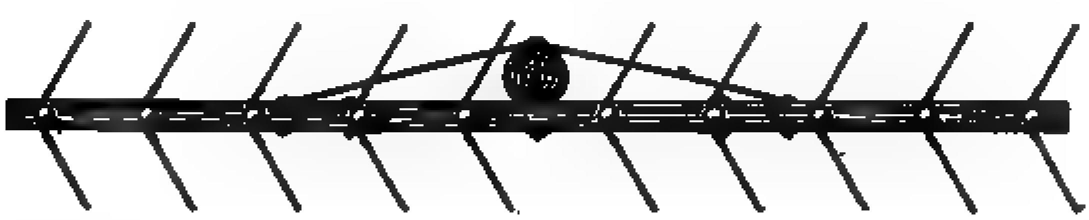


Fig. 141

ods of dead ending insulated wires are illustrated in Figs. 137-139.

188. Position of Wires: On straight lines the wires are placed on the sides of the insulators toward the pole, Fig. 140,

*See Art. 206 for a method of making the turns.

except the two wires adjacent to the pole, these being placed on the outer sides of the insulators. On curves and at corners, the wires are placed on the sides of the insulators toward the outside of the curve or corner as shown in Fig. 141. On bracket lines the wires are tied on the outer sides of the insulators.

189. Tension and Sag: Previous to tying the wires, the tension of each span must be adjusted,so that the **dip** or **sag** has the proper value. The wires hang between the poles in the form of long curves, and the tension required for a given amount of sag, depends on the weight and elasticity of the wires, and the length of the span. Changes of temperature affect the tension; an increase in temperature causing the wires to expand, which increases the amount of sag and decreases the tension; while a decrease in temperature causes the wires to contract, decreasing the sag and increasing the tension.

190. The wires should be so adjusted, that in the coldest weather the tension will not exceed a certain percentage of the breaking strength. One authority states that it should not exceed 33 per cent of this strength. Although it is possible to calculate the proper tension for any size of wire, length of span, and temperature, this method is somewhat complicated to use and requires a reliable dynamometer. It is usual, therefore, to adjust the tension by measuring the amount of sag or dip.

191. The sags for copper wires, from No. 6 to 10 B. & S. G., are given in the following table for different temperatures and lengths of span.

Temp. Degrees Fahr.	Length of Span in Feet								
	75	100	115	130	150	176	200	250	300
	Sag in Inches								
-30	1	2	2½	3½	4½	6	8	14	22
-10	1½	2½	3	4	5	7	9	16	25½
10	1½	3	3½	4½	6	8	10½	18½	29
30	2	3½	4	5½	7	9½	12	21	33
60	2½	4½	5½	7	9	12	15½	26½	44
80	3	5½	7	8½	11½	15	19	31	47½
100	4½	7	9	11	14	18	22½	36	55

The sags for No. 12 B. & S. G. copper wire should be at least 2 in. greater than those indicated in the preceding table.

The sags for iron and steel wires, having a diameter of $\frac{1}{10}$ in. and over, should conform to those for No. 10 B. & S. G. copper wire; and for iron or steel wires, having a diameter of less than $\frac{1}{10}$ in., should conform to those for No. 12 B. & S. G. copper wire.

192. The amount of sag is generally measured by a method known as sighting the wires. There are different ways of doing this, one method being to provide a rod, having at its top end a scale of inches, and a slide with a projecting pin, arranged to slip up and down this scale. This is used as follows: For each span the pin is set for the required sag. The rod is then set up at the center of the span and its height adjusted, until a lineman on the pole sights the top of the rod in line with the grooves of the insulators. The wire is then pulled up until it touches the pin. After one wire is adjusted in this manner, the others may be adjusted by comparison. Thus a man goes far enough away from the line to see when the other wires come up to the level of the first one, and then gives the signal to tie in. When the line is running up or down hill, the man with the rod should follow the deepest point of the curve in the wire.

193. The wire is pulled up to the proper tension by means of a come-along or similar tool. In case a dynamometer is used the tension may be obtained, if the proper amount of sag is known, by means of the formula

$$Tension = \frac{Span^2 \times weight\ per\ foot}{8 \times deflection}$$

In this the *span* and *deflection* or *sag* are in feet and the *weight per foot* in pounds.

If several wires are pulled up at the same time, apparatus as shown in Fig. 142 may be used.

194. Tying:* The wires are tied to the insulators with short pieces of wire, known as **tie wires,** frequently of the *same*

*Also called *tying in*.

size and *material* as the line wires. In case the tie wires are made of hard drawn copper wire, they should be thoroughly

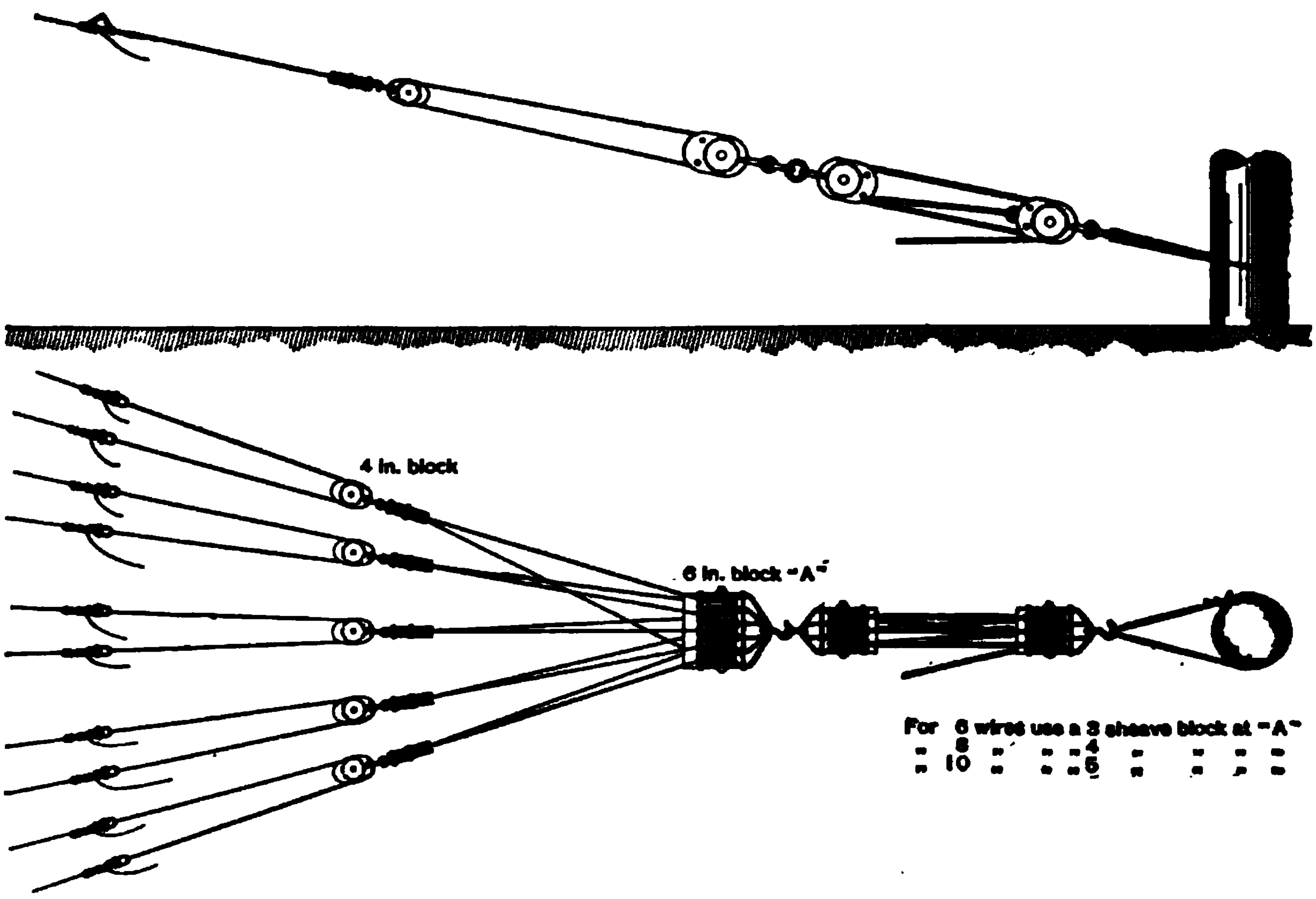


Fig. 142

annealed by heating them to a cherry red, and then allowing them to cool. In doing this care should be taken not to burn the wire or cause it to scale. If the line wires are insulated, the tie wires may have an *insulation* equal to that of the line wires, although *bare* tie wires are often used with weatherproof line wires.

195. The *length* of the tie wire is determined by the size of the line wire, and the size of the insulator. Lengths commonly used are given in the following table.

Line Wire B. & S. G. No.	Length of Tie Wire in Inches.
6	24
9	20
10	12–19
12	12–17

Tie wires for bare iron wire should be made of the regular line wire, and should be 19 in. long for No. 12 or 14 B. W. G. wires.

Annealed copper-clad tie wires for copper and copper-clad line wires are recommended to be two sizes smaller than the line wire.

196. *Copper* line wires, either bare or insulated, are often tied to the insulators in the manner shown in Fig. 143. It will be noticed that one end of the tie wire passes *over* the line wire and makes five complete turns, and the other end passes *under* the line wire and makes five complete turns.

Another method is to pass *both* ends of the tie wire *under* the line wire and then coil them around the latter, as shown in Figs. 144 and 145. *Iron* and *steel* wires, and sometimes copper wires, are tied to the insulators in the manner shown in Fig. 146.

Fig. 143

Tie wires are usually twisted around the line wires with the pliers or a tie wire wrench, the latter tool being used as shown in Fig. 147. Before making the last half turn the wire is nicked about half way through with the cutting pliers. Then

Fig. 144

when the half turn is completed the extra wire may be broken off by bending it back and forth once or twice at the nick, thus avoiding a projecting end.

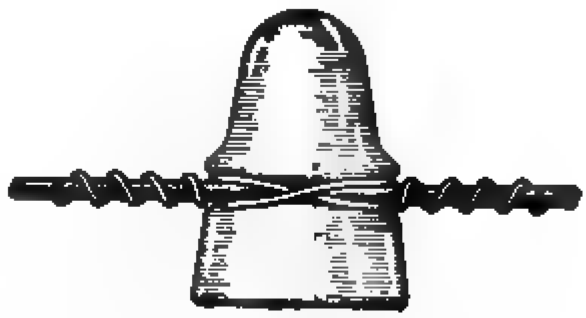
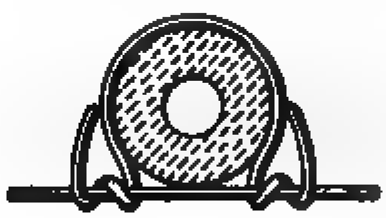


Fig. 145



197. *Twin* or *duplex wire,* which may be used in case all the cross-arms are full and it is necessary to run another circuit, is sometimes run through rings, or attached to porcelain knobs or rubber hook insulators on the *underside* of the cross-arms. This, however, is not very good practice.

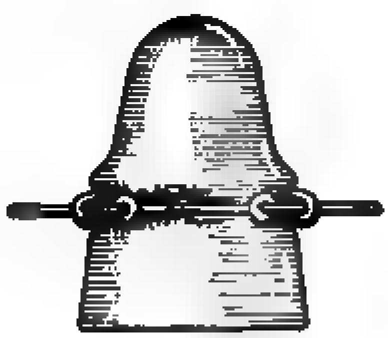


Fig. 146

198. Loop and Branch Lines: If it is desired to connect an instrument or device *in series* with the line, a **loop line,** or **loop,** is run from the main line to the instrument, and if it is desired to connect *in parallel* with the line, a **branch line,** or **branch,** is run. These are terms that are frequently interchanged, and do not definitely indicate the method of connection.

Fig. 147

199. Spider Wires: The terms spider wires and **bridle wires are** used in referring to wires run along the cross-arms for the purpose of making connections. These wires may be either extensions of the wires of a loop or branch line or they may be separate wires. In the latter case they are sometimes called **jumpers.** They are made of rubber covered wire and are carried along the cross-arms as required, by means of *spider wire cleats, bridle rings, porcelain split knobs,* or *pipe clips.* When several of these wires are to be run from one point to another, they are usually bunched together. Figs. 148 and 149 show two methods of running spider wires.

200. Trunking is frequently used to protect wires in carrying them from one location to another, such as in running them down a pole. It is also used in some cases to carry them along the cross-arms, as shown in Fig. 150, affording better protection to the wires than would be the case if they were exposed. The wires, at the points where they enter the trunking, are bent down to form

Fig. 148

drip loops, as indicated in the illustration, to prevent water from

Fig. 149

running inside the trunking. For the same purpose the en-

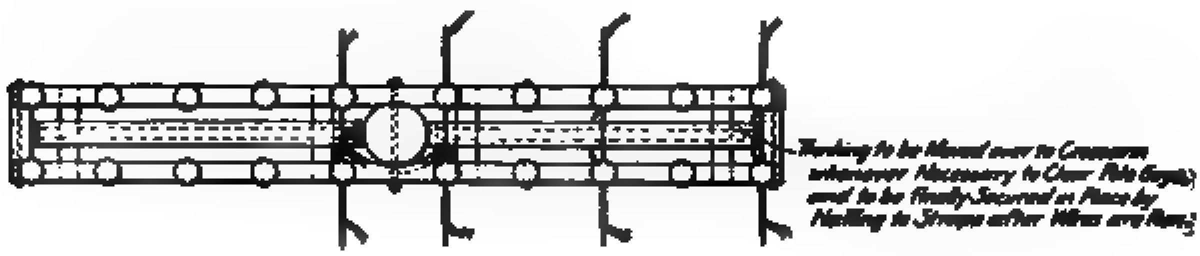


FIG. 150

trance-holes are bored at an angle slanting down toward the outside.

Fig. 151 shows a method of using *bituminized fiber conduit* to protect a loop or branch line on the side of a pole and underground. The conduit itself is protected by trunking where it runs along the pole and the opening at the top is protected by a hood to prevent the entrance of moisture.

201. For carrying wires on the sides of poles trunking may be used without the capping, the open side being placed against the pole. While this presents a better appearance, it is not so convenient to make changes in the wiring, since it is more difficult to remove the trunking than it would be to remove only the capping which is fastened with small nails or gate hooks.

202. In case a loop or branch line is run for some distance on insulators on poles*, one of the many methods of making connections to the main line is to attach a short cross-arm to the

*Cables are frequently employed for leading loops or branches off from lines. Their use will be described later.

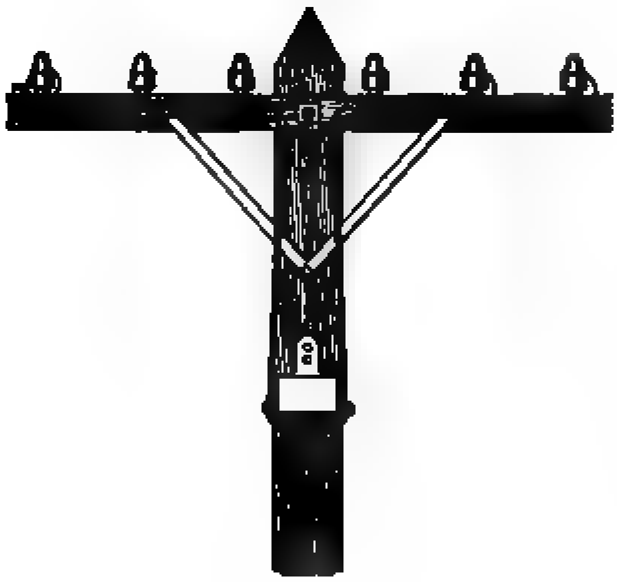


Fig. 151

main line pole, either below or above the regular cross-arms, or even between them in case it is not possible to use the other positions, and dead end the wires of the loop or branch line on insulators supported by this arm. Another method is to attach to the main line cross-arm, a *break arm* carrying insulators on which the loop or branch line wires are dead ended. Connections between the two lines are made by means of spider wires.

203. In some cases in running loops and branches, it is required that the pole and cross-arms be kept clear of short cross-arms, trunking, or other devices that would interfere with climbing it. In such cases it is necessary to erect a short **connection post,** in line with the main line, and run the loop down to it on an incline, as shown in Fig. 152.

204. Junction boxes, Fig. 153, are used as a convenient means of connecting the spider wires to the loop or branch lines leading to instruments or devices. A junction box may be located on a pole, the spider wires being bunched together and

Fig. 152

brought down the pole to the box in trunking, or it may be placed on a post near a pole, and the spider wires run to it from the pole top in a *hand made cable.* The post shown in the illustration is made of pipe. The wires leading to and from the junction box pass through the post, a passage for the wires being provided between the inside of the junction box at the top and the interior of the post. Wires are brought into the top of the post underneath a suitable cap, known as a *drip cap,* arranged to prevent the entrance of water. A hook bolt (a pole clamp is sometimes used) by which the wires may be supported, is attached to the post just below the drip cap. The base of the post is provided with openings into which trunking may be fitted for the purpose of leading wires to and from the post.

Fig. 163

WIRE JOINTS

205. It is frequently necessary to connect two pieces of wire, the connection being termed a **joint** or **splice.**

It is desirable that joints should be as nearly as possible mechanically and electrically as good as the wires they connect, without being soldered The principal object of solder is to prevent corrosion and consequent bad contact, although it generally increases the mechanical strength.

Hard drawn copper wire should not be soldered if the joint is to be subjected to tension, as the necessary heat anneals and weakens the wire. The fact that such joints are under tension, however, is considered to be favorable to maintaining good conductivity.

206. **Joining Iron and Steel Wire:** Iron and steel wires are usually spliced with the **Western Union joint***. The method of making this joint is shown in Fig. 154. The ends of the wires to be joined are cleaned, if necessary, lapped a sufficient amount, and clamped a little to one side of the center with a splicing clamp or hand vise. Then the shorter projecting end is caught with the pliers, or with the shoulder of a splicing wrench as shown in Fig. 155, and coiled tightly and evenly on the line wire. As there is generally more than sufficient wire to form the coil, the wire forming the extra end is nicked about half way through with the cutting pliers, at the proper point, before making the last half turn. The end may then be broken off when the coil is completed by bending the wire, thus finishing the coil without a projecting end. The coil formed in this manner is often termed a *knurl*. It is recommended that five complete turns, spaced $\frac{1}{16}$ in. apart, be made in each knurl.

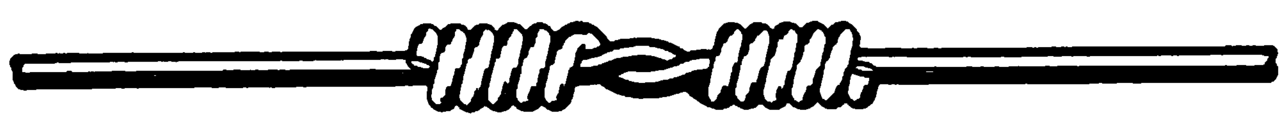


Fig. 154

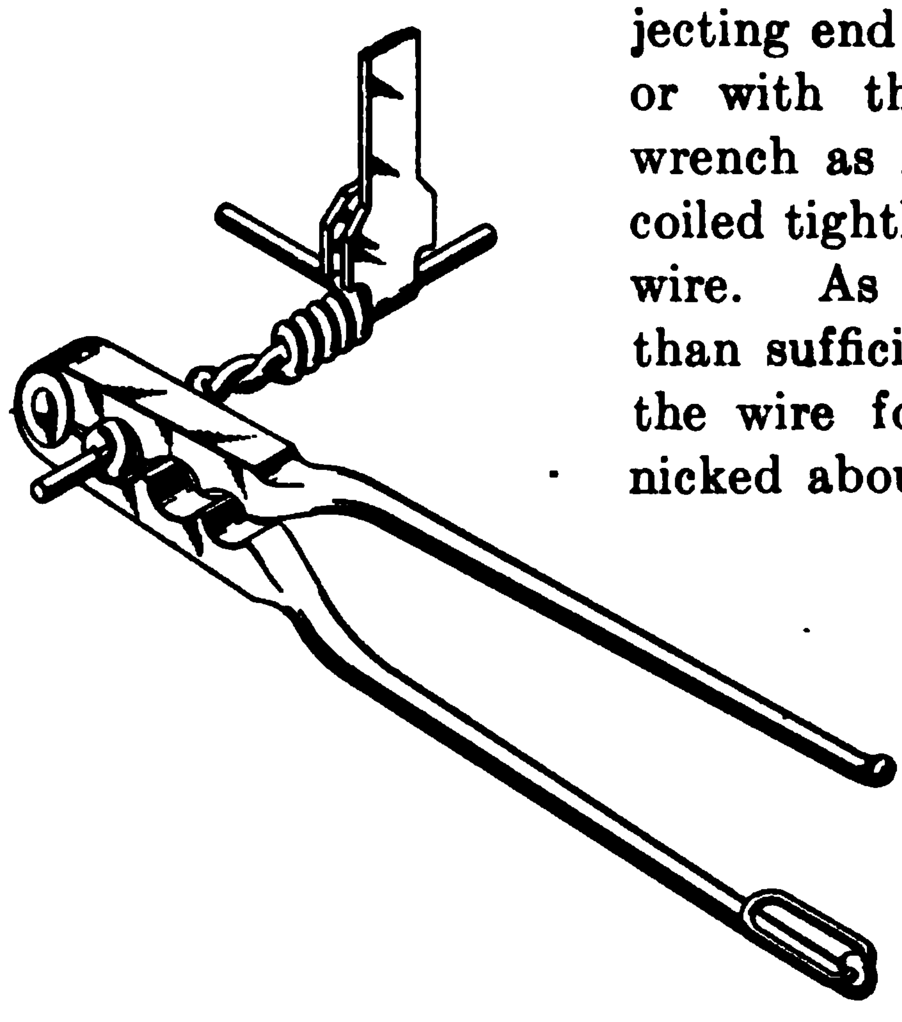


Fig. 155

The clamp or vise is now changed to the finished turns and the neck of the joint made by twisting the wires together, using

*Also called the *American joint.*

about one turn, although some authorities recommend more turns to the twist, making a longer neck, as shown in Fig. 156.

FIG. 156

The remaining end is now coiled to form a knurl as in the case of the first end.

Just before nicking the wire at this end preparatory to breaking it off, the joint should be given a strong twist, which draws the neck together more tightly, the joint being twisted as tightly as possible with an additional half turn or so, without injuring the wire.

207. Fig. 157 shows a form of joint knwn as a **three wire splice.** It is made by placing a piece of the same kind of wire, 8 to 12 in. long, alongside the two ends of the line wires to be joined, and clamping all three near the middle with a splicing

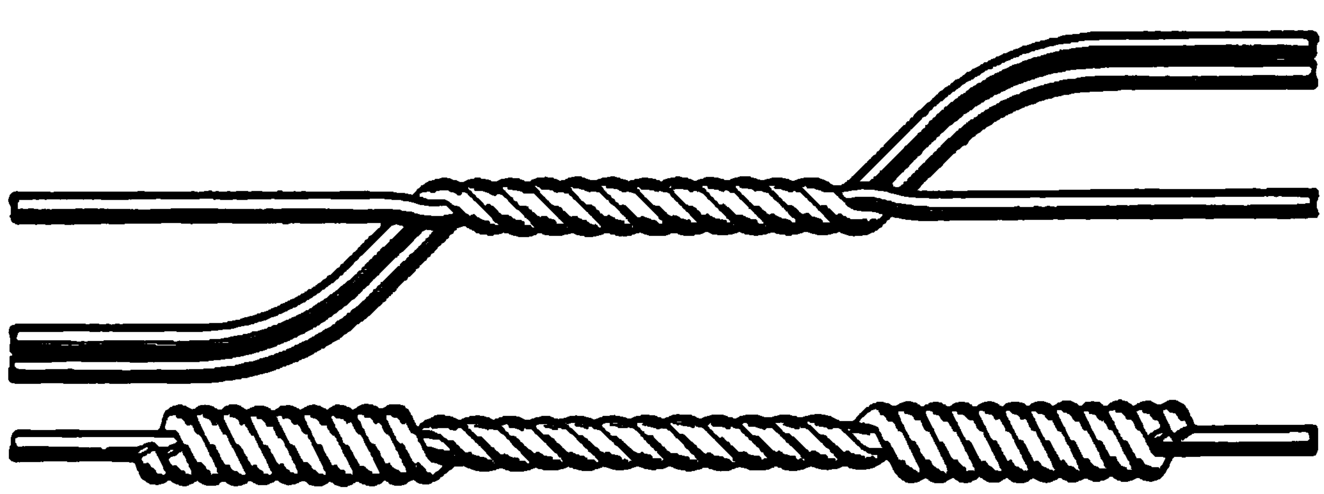


FIG. 157

clamp. The wires are then twisted and coiled as in the case of a Western Union joint, except that there are two ends to wrap around the line wire at each side, instead of one. This joint is said to be stronger and of better conductivity than an ordinary Western Union joint.

Where three wire splices are used it is recommended by one railroad, that they should be made with *knurls* not less than 1½ in. in length, that the space between knurls should not be less than 1½ in. and that the joint should be twisted as closely as possible, in the center between the knurled ends, without injuring the wire.

Joints in iron and steel wires are generally soldered.

208. Instead of joints made as described in the preceding articles, wire connectors may be employed for splicing iron and steel wire, although they are not much used at the present time.

209. Joining Hard Drawn Copper and Copper-Clad Wires: Joints in hard drawn copper and copper-clad wire are usually made with *wire connectors.* The ends of the wires are cleaned, if necessary, and slipped through the connector, the projecting ends sometimes being bent. One end of the connector is then clamped in a splicing clamp and, by means of the pliers, splicing wrench, or other suitable tool attached to the other end, both connector and wires are twisted, the completed joint appearing as shown in Figs. 50 and 52. The gauge of connectors should in all cases correspond with the gauge of wire used.

210. The number of twists recommended by one authority are given in the following table.

Wire B. & S. G. No.	Number of Twists	
	Single Tube Connector	Double Tube Connector
6	4½	3½
10	4	3
12	4	3

211. The following instructions for twisting McIntyre connectors are given by another authority.

When two No. 10 B. & S. G. copper wires are joined, the connector should be twisted 3½ full turns; for two No. 12 B. & S. G. copper wires, 5 full turns; for a No. 10 and a No. 12 B. & S. G. copper wire, 4 full turns; for a No. 10 and a No. 14 B. & S. G. copper wire, 6 full turns; and for a No. 12 and a No. 14 B. & S. G. copper wire, 5 full turns.

212. The Western Union joint and the three wire splice are sometimes used for hard drawn copper wire.

213. Although it is considered best not to solder joints in hard drawn copper wire that are to be subjected to tension. it is more satisfactory to solder those which are *not* subjected to

tension.

214. Joining Soft Drawn Copper Wires: Soft drawn copper wire as used in signal work is generally rubber covered. As it is usually not subjected to tension the mechanical strength of the joints is not so important; some of the joints used must be strong enough, however, to bear handling and resist rather severe strains at times. Joints in soft drawn copper wires are soldered in practically all cases.

215. The Western Union Joint, generally used for soft drawn copper wire, is made as already described, but need not be twisted quite as tightly as for line wire, although it should not be left loose.

216. Fig. 158 shows what is known as a **wrapped joint,** or a *Britannia joint.* The wires are brightened, bent slightly at the

Fig. 158

ends, and then wrapped together with a continuous tight serving of small copper wire. Finally the joint is carefully soldered.

217. A form of joint, known as a **running splice,** is shown in

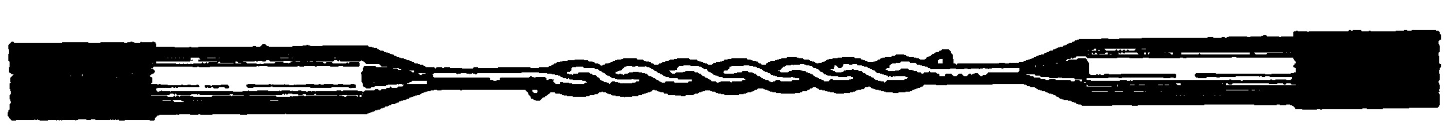


Fig. 159

Fig. 159. The wires are simply twisted together and the joint requires soldering to have the necessary mechanical strength. Another joint in which the wires are twisted together is the **pigtail** joint shown in Fig. 160.

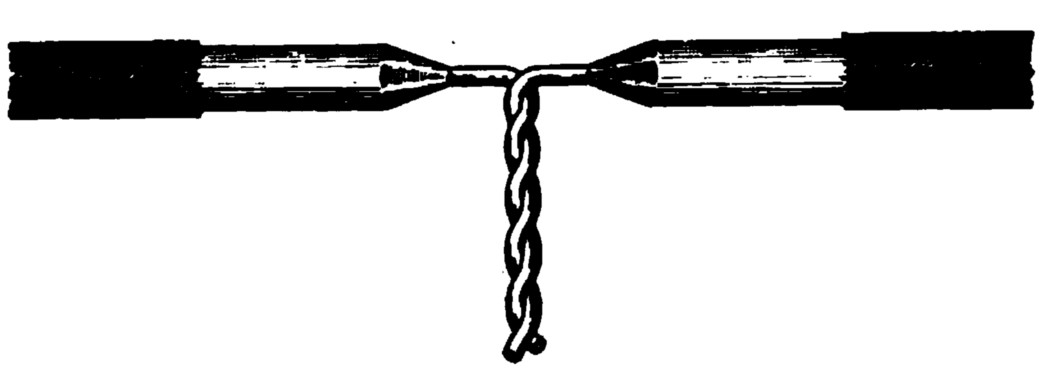


Fig. 160

218. A form of joint that is useful in connecting insulated

wires of different sizes is shown in Fig. 161. Another form of

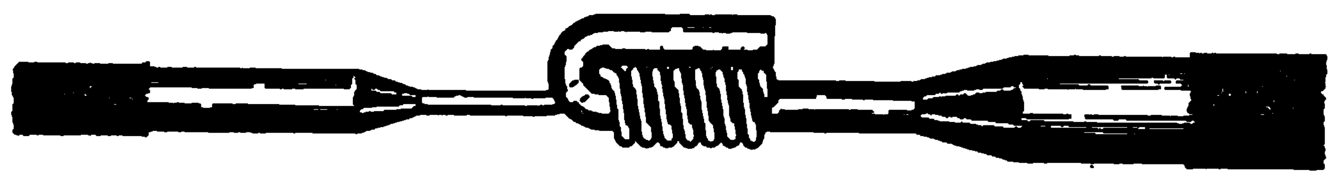


Fig. 161

joint for this purpose, in which the larger wire is coiled around the insulation of the smaller to aid in supporting it, is shown in Fig. 162.

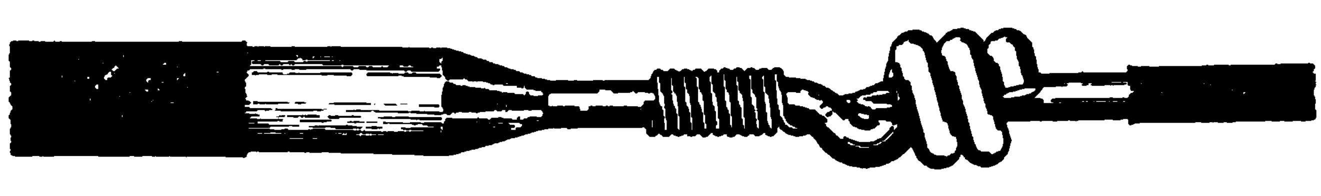


Fig. 162

219. Any of the joints described in Arts. 209-218, may be used for joining soft drawn to hard drawn copper wire or to copper-clad wire.

220. Taps: Joints, known as *taps,* where the end of one wire is joined to some portion along the length of another, without

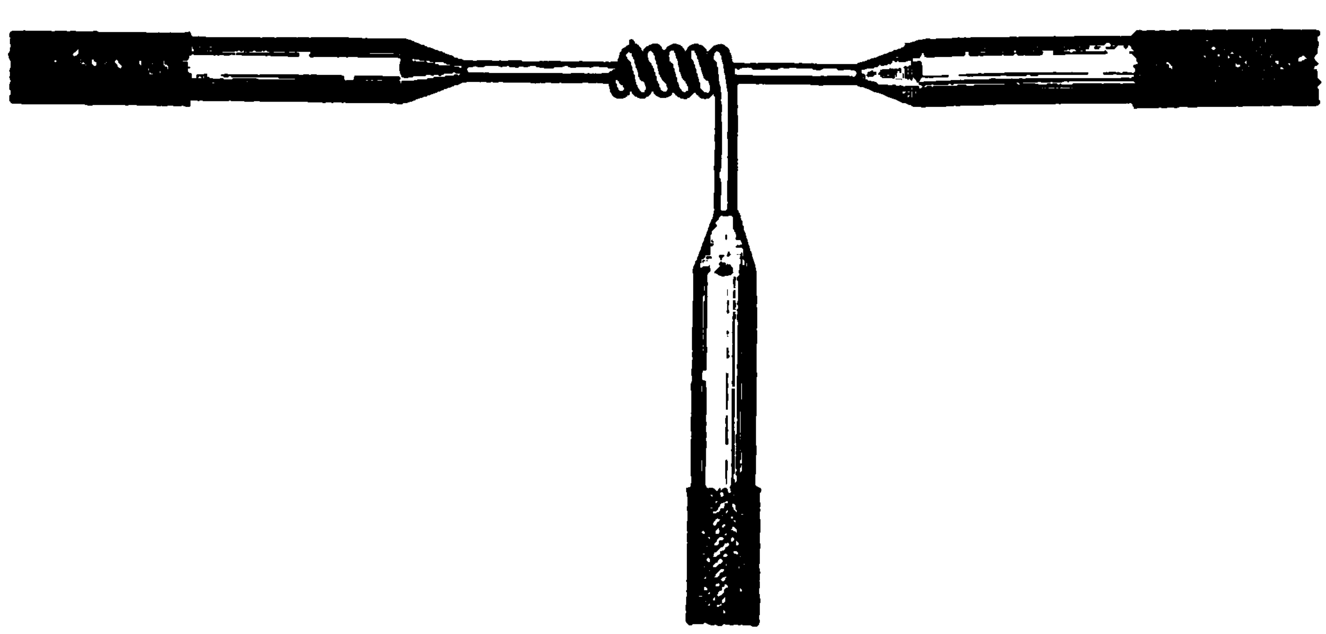


Fig. 163

cutting it, are often made as shown in Fig. 163, by tightly coiling the end of the branch wire around the through wire. It is recommended that five complete turns spaced $\frac{1}{64}$ in. apart be used, which forms practically one-half of a Western Union

joint. Figs. 164 and 165 show other methods. A double tap

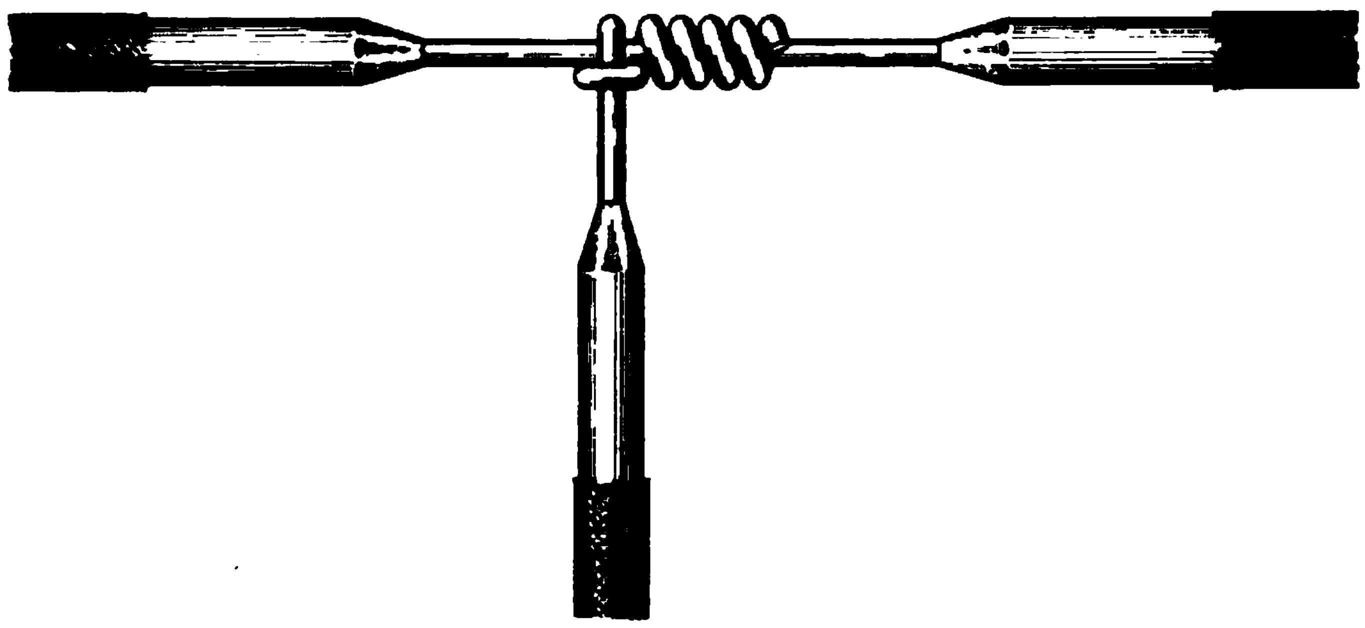


Fig. 164

may be made as shown in Fig. 166.

Taps are also made by the use of split connectors, the open

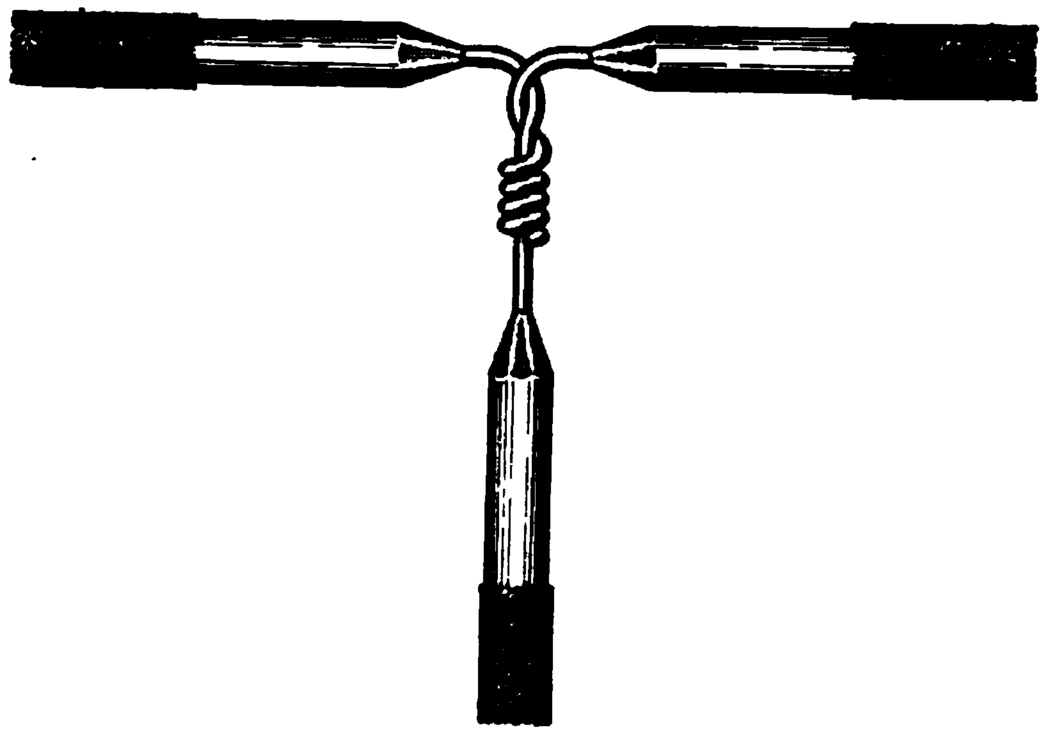


Fig. 165

side of which may be applied to the through wire without cutting it, as shown in Fig. 167. These connectors are twisted in the

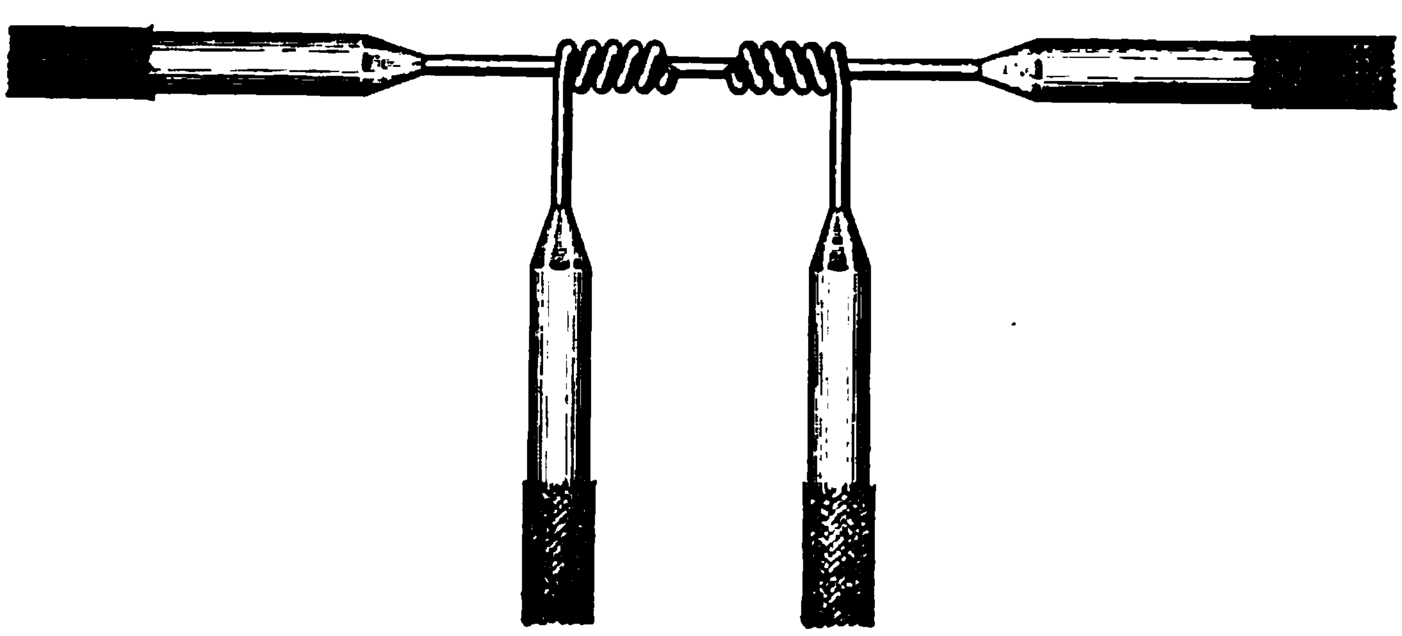


Fig. 166

same manner as ordinary connectors.

Fig. 167

221. Soldering: A joint may be soldered in a number of ways, the most approved methods being by *pouring* and *dipping*. The former method, which is the most common, is illustrated in Fig. 168. It is considered that by this method there is less danger of weakening the wire by overheating it, than by the methods which require the joint to be dipped into molten metal, or heated with a gasoline torch.

222. The solder, usually common *half and half* bar solder*, Fig. 169, is first melted in a *melting pot***, heated by a *gasoline furnace***, care being taken not to get it too hot. It should only be hot enough to flow freely and may be considered to have reached the proper temperature, if it just

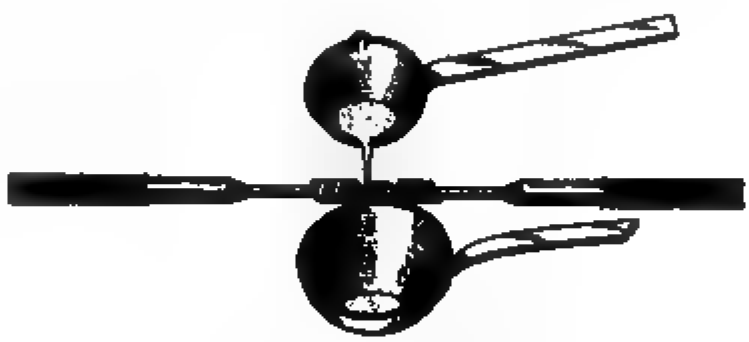


Fig. 168

lights a chip of soft wood, when the latter is plunged into it for a few seconds. The *ladles*** are heated while the solder is

Fig. 169

melting, or before they are used, so that they will not chill the

*See Materials,—*Lead*.
**See Tools.

molten metal.

223. After the wires have been cleaned, if necessary, and the joint made, it is coated with a suitable flux, the purpose of which is to allow the solder to adhere to the metal, by keeping the wire clean and preventing it from oxidizing when heated.

224. The use of a non-corrosive rosin flux is recommended for this work. Such a flux may be made by dissolving 1 lb. of rosin in 1 qt. of grain alcohol. Among other fluxes the following may be mentioned: Tallow candles, lard, plain rosin, and the zinc chloride flux suggested by the National Board of Fire Underwriters, which is made by mixing 5 parts of a saturated solution of zinc chloride, 4 parts of alcohol, and 1 part of glycerine.

225. The use of ordinary zinc chloride fluxes is generally considered bad practice, on account of their corrosive action, if not thoroughly removed after soldering is completed. In the case of bare iron line wire, however, they are generally satisfactory, as rain usually washes them off before they can cause any trouble.

If the flux is in the liquid form, it is generally applied with a small brush. Paste is simply rubbed over the joint, while solid flux is applied after warming the joint slightly.

226. After first removing the scum or dross that forms on top of the molten solder in the melting pot, a suitable quantity of solder is taken out with the smaller ladle and poured upon the joint, that which runs off being caught in the larger ladle. If the solder does not adhere to all parts of the joint at the first pouring, more flux is applied and the solder again poured over the joint. When the joint is completely covered, the surplus solder is removed from the underside with the edge of the ladle.

If a number of joints at the same location are to be soldered by this method, it is well to have them prepared, as a matter of economy, so that all may be soldered at one time.

227. When a joint is to be soldered by dipping, it is prepared as described in the preceding articles, and then dipped into the molten solder in the melting pot or ladle, the wire being bent so that the molten metal will not injure the insulation.

228. Another method that is employed, is to heat the joint and melt the solder onto it by the use of a hot soldering copper. Solder is used for this method in the form of sticks, wire, small tubes with the hole filled with flux, or finely divided solder mixed with flux in the form of paste.

229. In order that the soldering copper may work well, the end that is placed in contact with the work and solder must be kept *tinned;* that is, coated with a thin layer of solder. A convenient way of doing this is to rub the point of the hot copper on a common brick, on which powdered or small pieces of rosin or sal-ammoniac have been placed. In this way the point is cleaned and at the same time covered with flux, so that it will readily receive a coat of solder when the latter is melted upon it.

230. Another method is to file the copper clean with a coarse file and then heat it to a good heat, dip it into sal-ammoniac, and finally rub it in a mixture of solder and flux on a piece of bright tin.

231. Care should be taken not to overheat the soldering copper as it becomes pitted and sometimes covered with a hard scale that is difficult to remove. In this condition it is said to be *burned.*

232. Still another method of soldering a joint is to heat it with the flame of a gasoline torch, and apply the solder in the form of wire or tube when the joint is hot enough to melt it; or the solder, if mixed with the flux in the form of paste, may be applied before starting to heat the joint. If this method is used care should be taken not to overheat the joint.

233. In making joints in rubber covered wires, the insulation is first removed from those portions of the wires which are to form the splice, allowing ½ to 1 in. more of bare wire than is

FIG. 170

required for the joint. The insulation is removed with a knife held at an angle of about 30 deg., care being taken not to cut into or injure the metal. On completing the removal of the

insulation the wires should present the appearance shown in Fig. 170. It will be noted that the rubber is beveled in a manner, similar to that in which the wood of a pencil point is cut, and that the braid is peeled back about 1 in. from the high point of the bevel. It is important that the copper be clean and bright, which condition is produced by scraping it carefully with a dull knife blade, care being taken not to nick or cut the surface. Emery cloth and sand paper are often used instead of the knife for this purpose.

234. After the ends of the wires are prepared, they are connected by a suitable joint, such as a Western Union joint shown in Fig. 171, the joint being soldered. The distance between the

Fig. 171

end of the knurl and the high point of the bevel, where the rubber insulation is tapered to meet the wire, should be about $1\frac{3}{8}$ in.

235. After soldering, the joint should be thoroughly cleaned by wiping off with a piece of wet cloth or waste and drying, and then both the wire and the exposed rubber insulation given a coat of pure rubber cement, which should be allowed to set, this taking about one minute. In place of rubber cement the joint may be coated with a suitable insulating paint, such as P. & B. electrical compound.

236. The joint is now wrapped spirally with rubber tape, starting at the bevel on a level with the insulation, Fig. 172, and continuing as far as the high point of the bevel on the other side

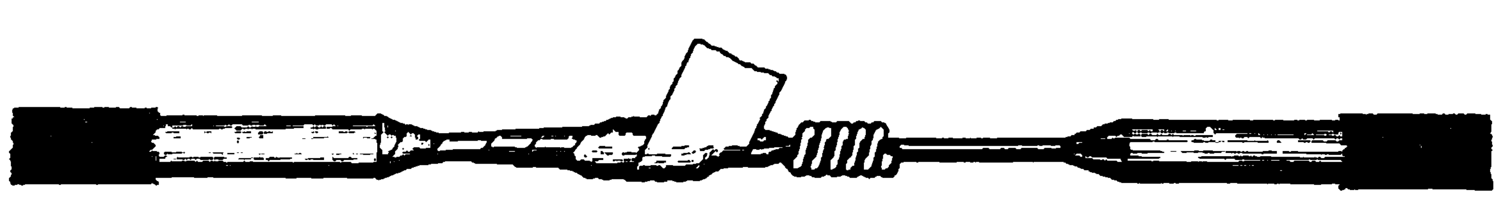


Fig. 172

of the joint. The wrapping process is continued to and fro, Fig. 173, until the insulation is built up slightly thicker than the regular wall. The tape must be put on under tension, so that it

is stretched to about half its width, and so that the turns overlap about half way. In carrying out this process everything should

Fig. 173

be kept clean. The layers may be caused to adhere more firmly after application, by applying heat from a spirit lamp, match, or the hand, evenly around the joint for about one minute. Care must be taken not to burn the rubber if a flame is used.

237. A coat of suitable insulating paint should now be applied over the rubber tape and should extend out over the braiding.

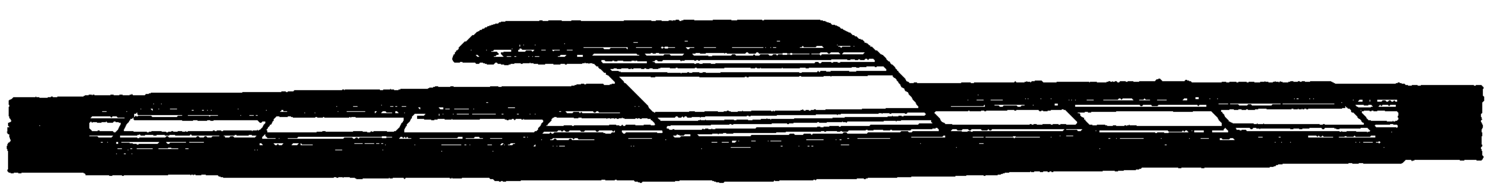


Fig. 174

After this two layers of friction tape, half lapped, are applied, Fig. 174, being carried over the ends of the braid, and another

Fig. 175

coat of insulating paint is applied to the outside. Fig. 175 shows the completed joint.

238. The solvent used for P. & B. electrical compound is very readily evaporated. This material, therefore, should be kept in good tight cans securely sealed, and care should be exercised to have the tops screwed on tightly when the material is not in use. In using from large packages, it is well to pour out a small quantity at a time, so as to avoid having the entire package open. If the material thickens on account of evaporation of the solvent, it can be thinned by using regular P. & B. thinner, which is compounded by the manufacturers. The manufacturers state that no other thinner should be used.

P. & B. black air drying varnish, which is also used very ex-

tensively for making joints, may be thinned by the addition of 62 deg. benzine.

239. Another method of applying the insulating covering to a joint is as follows:

After the joint has been made, soldered, and properly cleaned, as in the case of the preceding method, it is wrapped with one or two layers of pure rubber splicing strips. These are applied spirally under tension, so that they are stretched to about half their width, and so that the turns overlap about half way. This covering should extend at least half way up the bevel, on the ends of the original insulation on each side. Over this Kerite tape is wrapped spirally, half lapped, with the heavy coated side inside, several layers being applied, and the last two or three being carried out over the braid. A sufficient amount of this tape should be applied to make the thickness of the insulation on the finished joint somewhat greater than that of the original insulation. Finally the joint is finished with a coat of suitable insulating paint. The purpose of the pure rubber strips is to protect the wire from the action of the sulphur in the tape.

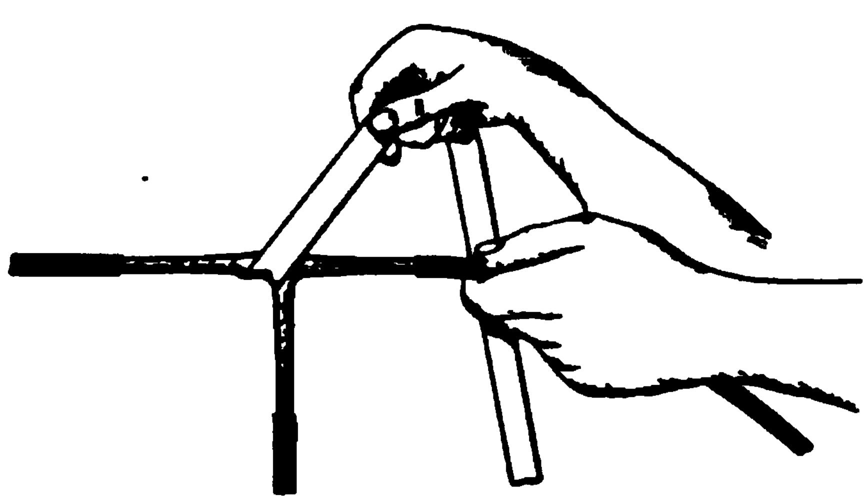


FIG. 176

240. A tap is insulated by first applying rubber tape to the straight portion, in the same manner as in the case of an ordinary joint. Then starting at the high point of the bevel on the insulation of the branch wire, tape is applied spirally, as in the case of an ordinary joint, until the junction of the wires is reached. To insure a moisture proof covering at this point, the tape should be wound into the corners as illustrated in Figs. 176-178, the

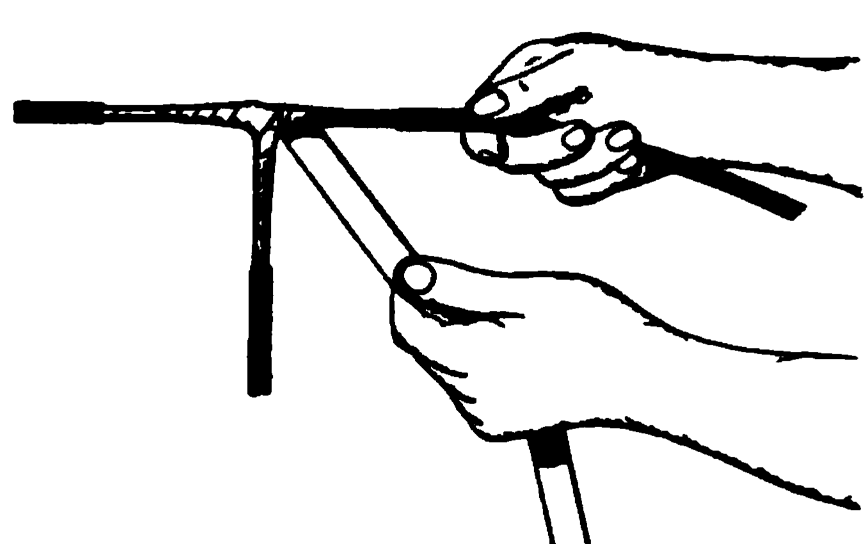


FIG. 177

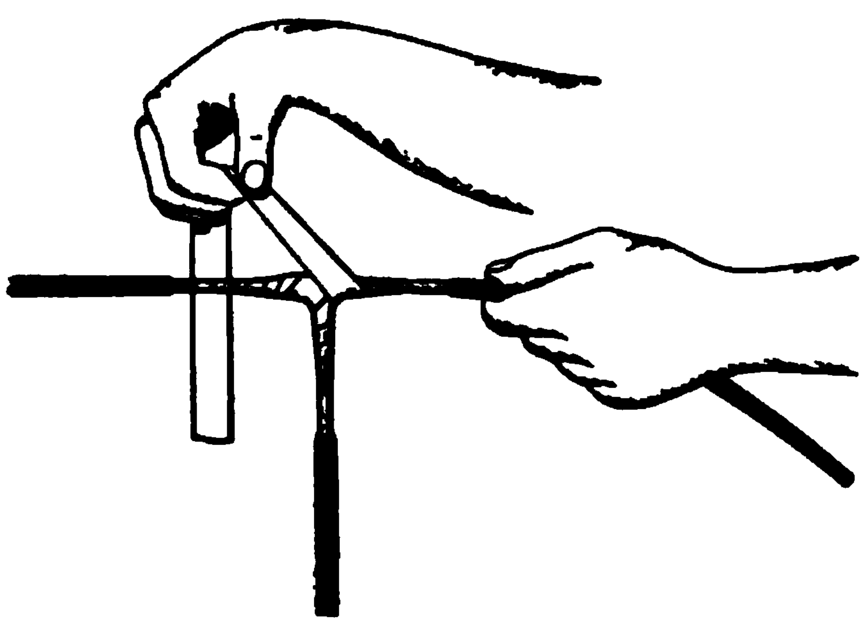


FIG. 178

joint, when the rubber tape has been applied, appearing as shown in Fig. 179. Care should also be taken in applying the friction tape to entirely cover the rubber tape in all the corners. Fig. 180 shows a completed tap, the friction tape having been applied.

241. Some further notes on making joints in insulated wire are as follows:

242. Joints made with *McIntyre sleeves* should have the ends

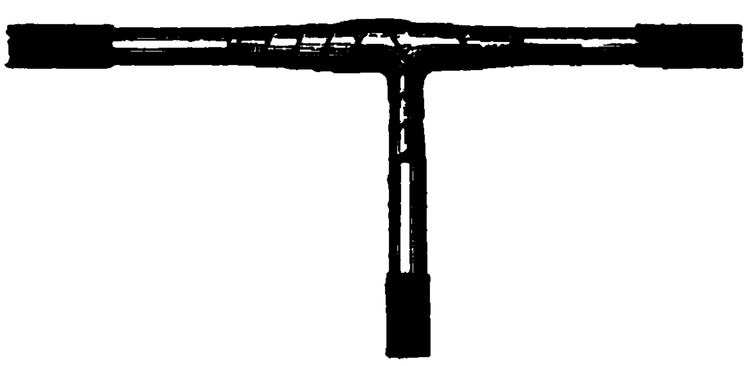


FIG. 179

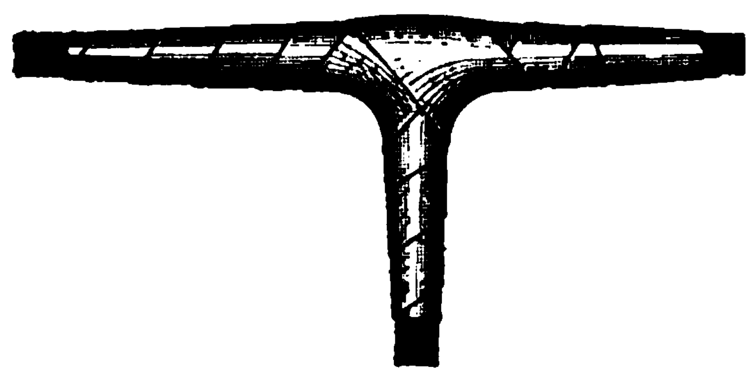


FIG. 180

cut square and not bent over to prevent cutting through the tape.

243. In one method of making taps to through copper line wires, the wires should be scraped bright and the branch wire closely coiled, for a distance of not less than 2 in., around the line wire. The joint should then be covered with tin foil, and wrapped with two layers of rubber tape and two layers of friction tape. The purpose of the tin foil is to prevent the sulphur in the rubber tape from acting on the copper. When taps are made to through iron line wires, the preceding directions should be followed, except that the joint should be soldered and the tin foil covering omitted.

244. Joints made in *weatherproof line wire* with McIntyre sleeves, are often insulated by simply wrapping them with friction tape. In some cases the joint is coated with P. & B. compound before and after the application of the tape.

245. Joints in *duplex paired* or *twin wire* are made in the

same manner as joints in single wire, with the exception that they should be *staggered*, so as not to come at the same place in both conductors. Care should be taken so that when the joints are completed both wires are of the same length, thus preventing one of them from taking more of the strain than the other. After the joints are made the wires are sometimes bound together with friction tape.

246. Running through Trees: Trees are trimmed with a hand saw or hatchet when the desired places can be reached with these tools. The clearance required around the wires varies according to conditions, but 2 ft. is generally sufficient, provided trimming is done often enough to keep that clearance. Where the hatchet will not reach, the tree trimmer is used. Care should be taken to disfigure shade trees as little as possible.

247. When wires run through trees, which cannot be trimmed sufficiently to prevent any possibility of their branches coming into contact with the wires, the wires should be supported on tree brackets or tree insulators. Another method which may be used is to split a piece of bamboo into halves, cut out, with a gouge, the knots which occur in the cane and lash the halves around the wire where abrasion is liable to occur. It has been found, that the hard surface of the cane resists the abrasive action of swaying branches, for almost an indefinite period.

248. Transpositions: Parallel wires carrying currents which vary in value, such as alternating currents, have an inductive effect upon one another. In some instances this effect is detrimental to the service, as in the case of telephone wires. The method generally used to overcome this effect is to cause each

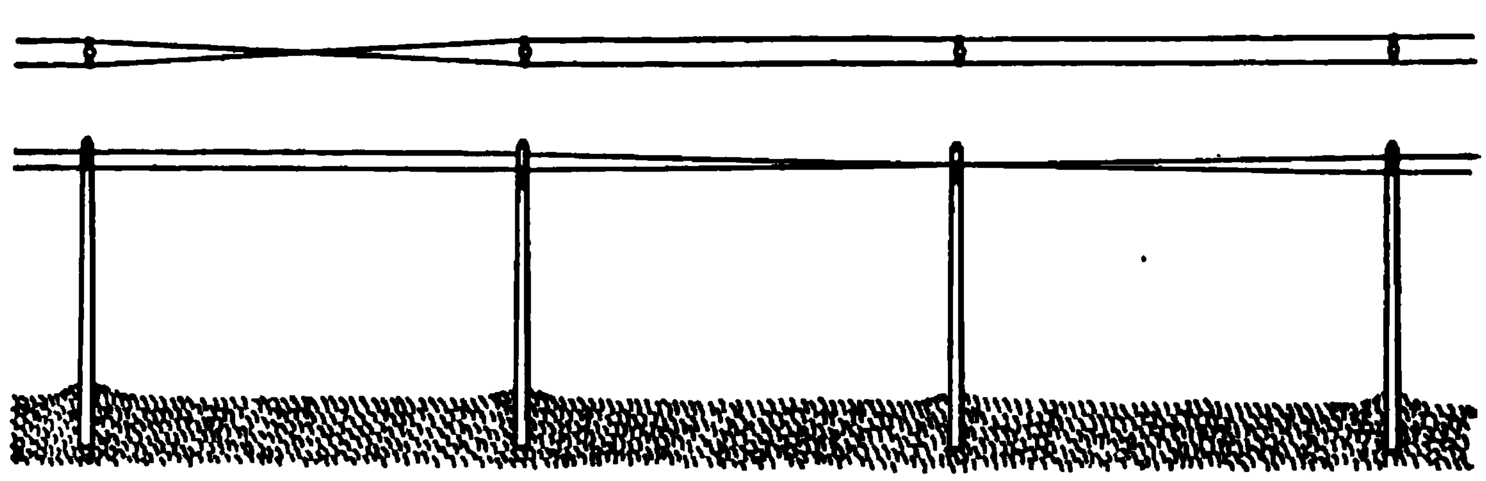


Fig. 181

half of the circuit to frequently interchange position with reference to all other neighboring circuits. Arranging the wires in this way is called *transposing* them, and it is said that a *transposition* is made at the points where the wires interchange positions.

249. If transpositions are to be used on a line carrying two wires attached to the poles by brackets, one transposition, as shown in Fig. 181, should be made at every thirtieth pole. This method is termed a *rotary transposition.* On a short line the wires should be transposed in the center.

250. When wires are carried on cross-arms, various methods are employed in making transpositions. Those described in the

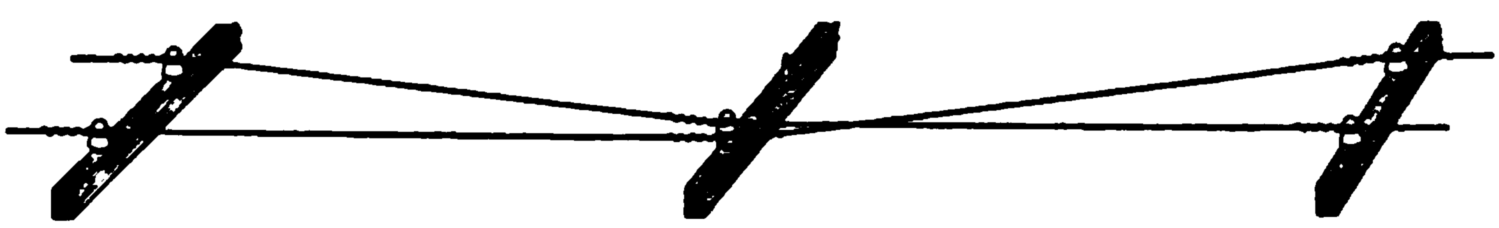


FIG. 182

following article are recommended for telephone work, in which transpositions are most commonly used.

251. When wires are being strung the transpositions may be made as shown in Fig. 182; otherwise they may be made as

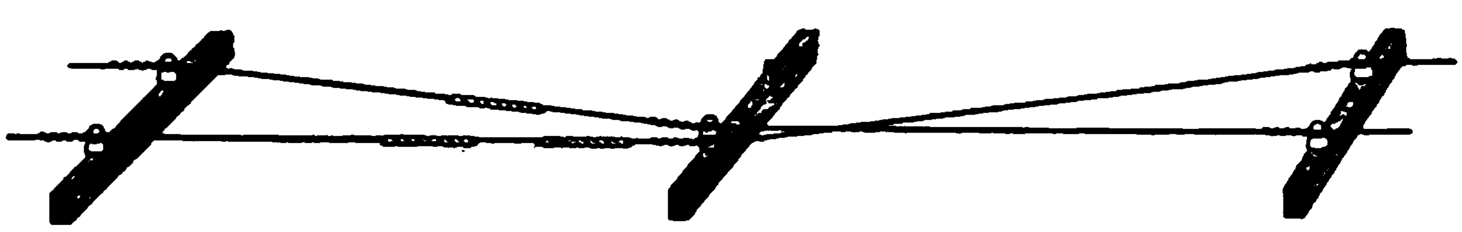


FIG. 183

shown in Fig. 183. In this case the wires should be cut, so that two of the ends to be joined will overlap sufficiently, to enable the joint to be made with one connector. In order to join the other two ends, however, two connectors and an extra piece of wire will be required. Fig. 184 shows another method of making transpositions.

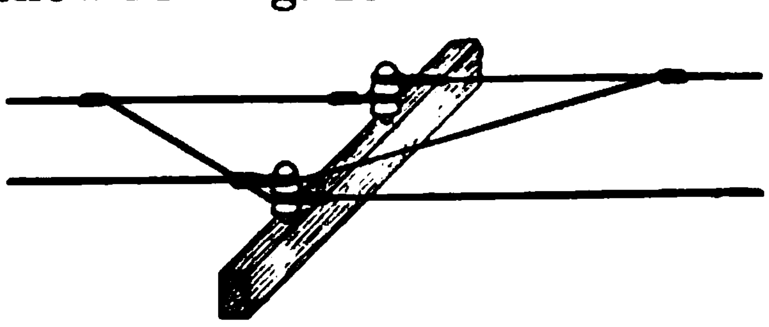


FIG. 184

252. Cradles: These are devices used where high and low tension lines cross, or where a line crosses a highway, railway,

etc., to prevent the wires from falling in case they break or for any other reason, and also to ground a broken wire before it can cause damage to other wires, property, etc. They are made in various ways from strands, wires, and wooden slats.

253. A method of protecting low tension wires, where high tension wires cross above them, consists in connecting the pole tops of the low tension line, by a grounded steel strand of sufficient size to carry three or four times the ordinary current flowing in the high tension line, and placing between this and the low tension line wires a series of twelve parallel galvanized iron wires, attached to a cross-arm at each end and also grounded.

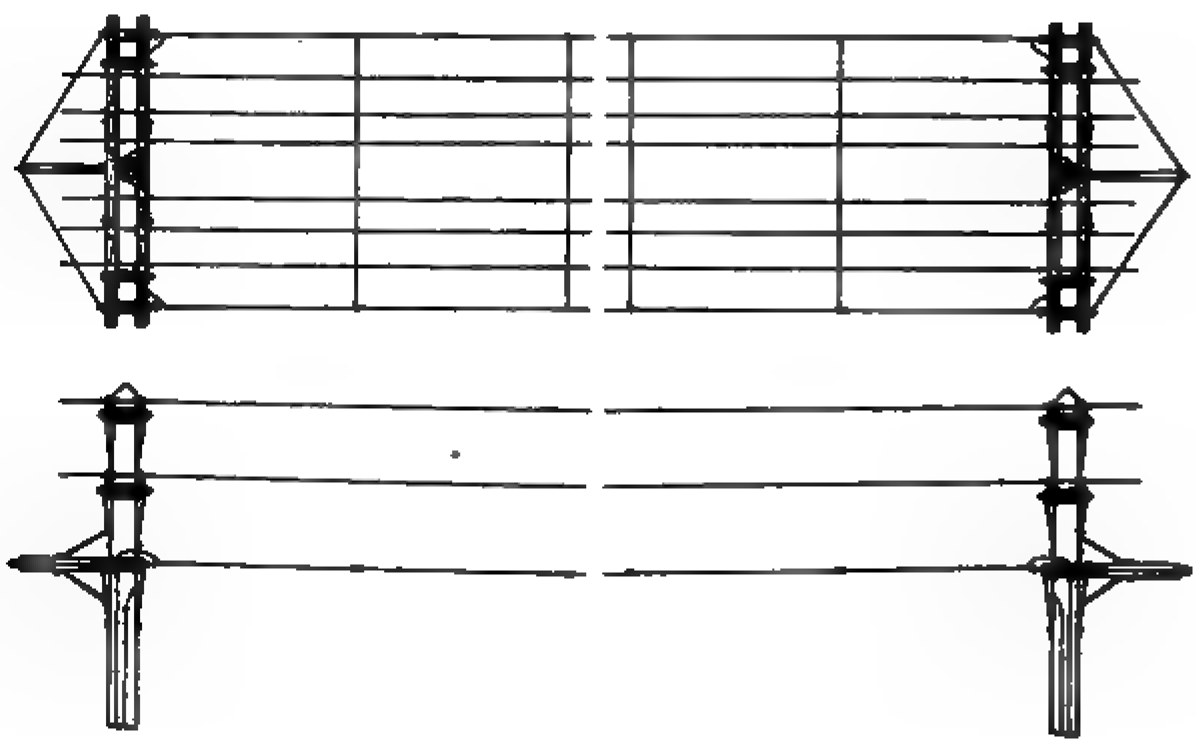


Fig. 185

254. Fig. 185 illustrates a method of preventing low tension wires from falling on high tension wires crossing below them, or onto the track or highway. It consists of extra long cross-arms, placed below the regular cross-arms, between the ends of which

a pair of grounded steel strands or large hard drawn copper wires are stretched. These are joined at regular intervals by cross wires of galvanized iron or hard drawn copper, secured by twisting them around the two supporting wires or attaching them by means of guy clamps. Two ground wires are used at each pole, one being connected to each of the supporting wires.

255. Entering Buildings: When wires enter buildings the following general directions should be observed. The wires should enter at a dry place, and whenever possible under a projecting roof. Where they pass through the wall, Fig. 186, they should be run through tubes, generally of porcelain. These tubes should slant upward toward the inside and the wires should be bent down into loops, known as **drip loops,** before they enter the tubes. Both of these precautions are to prevent water from running along the wires into the wall.

If there are several wires they are frequently formed into a cable and run to a building in this form.

Fig. 186

256. Lightning Protection: Such protection is generally obtained by installing lightning arresters.

Another method of securing lightning protection for the line, is to run a grounded wire or wires above it, in such a position that the wires of the line are within a space, enclosed by the sides of a 45 deg. angle, extending from the ground wire or wires downward.

Overhead ground wires or guard wires should consist of galvanized iron wires either solid or stranded. If one wire is used, it is generally run on insulators set on pins placed in the pole tops, as shown in Fig. 110. The insulators are not necessary, but afford a convenient means of supporting the wire.

At intervals the overhead ground wire is connected to the earth by ground wires stapled to the poles. The number of ground wires employed varies according to the amount of protection required. In some cases it may be found desirable to have one on each pole, while in others it may be sufficient to place them on poles a half mile apart.

257. This method of placing a grounded wire or wires above the line affords to a certain degree the same protection that would be obtained if the line were run underground, although by no means so complete. Simple ground wires or lightning rods stapled to the poles afford protection of the same kind, but to a lesser degree.

258. *Ground Connections.* If it is possible, ground plates*, rods, and pipes should be placed in or reach soil that is permanently damp, or maintained so artificially. When plates are placed in streams of running water, or in dead water, they should be buried in the mud along the bank, in preference to merely laying them in the water. Where there are metal bridge structures, grounds may be sometimes be obtained by connecting the ground wires to them. However, ground wires should not be connected to structures, that are used as return circuits for dynamic current.

259. All connections between the parts of the circuit leading to the ground should be soldered if possible. If a ground pipe is used a good method of attaching the ground wire is to solder it to a brass pipe fitting, such as a plug or cap, and screw the fitting to the pipe.

260. Grounds should be tested when completed* to insure that their resistance is sufficiently low, the maximum permissable resistance being about 50 ohms. In some cases two or more ground pipes or rods, placed about 6 ft. apart, may be used to obtain a better ground, and salt is sometimes used around ground plates, pipes, or rods to aid in keeping the earth damp.

261. When ground plates are used, it is considered better to braze the ground wires to them in place of soldering, the plate

*See Magnetism and Electricity.

and connection being tinned after the brazing is completed. The operation of *brazing* is accomplished as follows:

262. The wire and portion of the plate where the joint is to be made are cleaned, after which the wire is fastened to the plate, so that it will stay in position when heated. A flux, preferably consisting of borax, which has been fused to drive off the water of crystallization and powdered, is then applied to the joint. The addition of about one-third of powdered boracic acid, sometimes improves the action of the flux.

263. The spelter or solder is an alloy of about equal parts of copper and zinc, or if a harder spelter is desired, two parts of copper to one of zinc. This may be applied either by being pulverized and mixed with the flux, or in the form of wire.

264. When the joint has been prepared it is heated with the flame of a gasoline torch until the spelter melts. This requires a bright cherry red heat. If the wire form of spelter is used, it is applied after the joint has reached the proper temperature. A hot flame is needed for this work and the joint should he heated to the proper temperature as quickly as possible. More flux may be added during the operation if it is needed. In some cases a clean forge fire will furnish a more satisfactory heat than the gasoline torch, especially if the work is large and of good heat conducting material, such as copper.

265. Tagging: Tags of sheet metal are sometimes attached to the wires for the purpose of identifying them so that circuits may be easily traced. The tags are lettered or numbered to correspond to the pole line diagram, and are located near insulators usually at terminal poles, or where changes in the arrangement of the circuits are made. They may, of course, be used at any other points as convenience requires. They should be so attached, in connection with the tie wire, that they cannot slip along the line wire into the middle of the span.

In some cases, instead of attaching the tags to the wires, they are nailed to the cross-arm directly below the insulators to which the wires are tied.

MAINTENANCE

266. Systematic inspections of the line should be made, at the same time trimming trees, replacing broken insulators or tie wires, tightening guy wires and slack line wires, and in general keeping the line in the same condition as when it was first built. Rotten cross-arms and pins should be noticed and replaced at the earliest opportunity.

267. Grounds should be tested periodically to insure that they remain good; that is, that their resistance remains sufficient ly low. If the resistance is high due to dry ground, several handfuls of salt placed on the ground at the top of the ground rod or pipe, and wet occasionally with a pail or two of water, will tend to reduce the resistance, as the brine soaking into the ground aids in retaining moisture around the rod.

268. In cutting out the slack, when tightening slack line wires, care should be taken not to pull one wire tighter than others of the same kind in the same span.

269. If the surface of a pole is badly cut by the spurs of climbers, it should be provided with pole steps, so that lineman will not be in danger of falling.

270. Alterations: In making alterations the service should be interfered with as little as possible. Thus if a line is to be moved to a new position, the best method is usually to leave the old line in service until the new line is built. When the wires are strung they are joined to the old line, at the ends of the new section, with half connections; that is, half a Western Union joint. That portion of the old line, that has been bridged by the new section, is then taken down, the connections to the new section being completed to make regular Western Union joints.

If sleeve connectors are to be used, temporary connections may be made with test connectors, until the old wires are cut, the sleeve connectors then being applied in the regular way. By using jumpers* to bridge joints which it may be necessary to open**, as when substituting sleeve connectors for test connectors, changes can usually be made without interrupting the circuits.

*Usually made of a few feet of office wire or small rubber covered wire.
**That is to separate the ends of the wires.

271. When making joints in wires already strung, as in repairing a break, the wires are pulled up by two come-alongs attached to each end of a tackle. In the case of a break the procedure is as follows: A suitable length of wire is spliced to the longer end of the broken wire. This length of wire is then joined to the shorter end, the latter of course being cut off to a suitable length for joining. As some slack is required in making this joint the wires should be pulled somewhat tighter than the required tension, so that when the joint is made and the come-alongs removed, the sag will be the same as in the other wires of the span.

272. It is sometimes necessary to attach another cross-arm to a pole, and at the same time undesirable to place it below the other cross-arms, on account of some reason such as insufficient clearance for the wires. In such a case use may be made of a method known as *splicing up a pole,* Fig. 187. This consists in bolting two timbers, for example pieces of cross-arms, to the sides of the pole as shown, the extra arm being attached to them with lag screws or bolts.

273. When it is necessary to move a pole only a few feet, the method known as *ditching* or *trenching* is sometimes more convenient and less expensive than pulling up the pole and erecting it again. It consists in digging a ditch or trench from the new hole to the butt of the pole, the trench being of the same depth as the hole and wide enough to permit the passage of the pole butt. The pole, which must be temporarily guyed with ropes to pervent it from falling, is then worked along the trench in its upright position to the new hole, after which the ground is

Fig. 187

tamped around it in the ordinary manner. With this method it may in some cases be unnecessary to even untie the line wires.

LOCATING FAULTS

274. Faults may be divided into three general classes as follows:

First. **Open wires,** in which case the wires are broken and insulated from the earth and other wires.

Second. **Grounded wires,** in which case the wires are in electrical connection with the ground.

Third. **Crossed wires,** in which case two or more wires are in electrical connection with one another.

275. The conditions which produce faults may, of course, vary considerably. For example, a very high resistance may develop in a joint, and produce the same effect as an open wire; or where a wire runs through trees, the insulation may be chaffed off, and a ground formed by the bared wire cutting through the bark to the sap wood of a limb. Combinations of faults may also occur. Thus a wire may break, one end falling into a pool of water and becoming *grounded,* while the other end is suspended in the air and is *open.*

276. The following are general methods of locating faults. Later in the course, after various signal instruments and their connections have been described, other practical tests will be given, which depend more or less upon the operation of these instruments.

277. Open Wires: Faults of this kind may usually be readily seen by a lineman passing along the line. Thus in the case of bare wire, such a fault may be produced by the wire breaking, and in falling hanging over some insulating object, such as a dry wooden roof or fence. In the case of insulated wire the fault may be produced by the wire breaking and falling, the insulating covering preventing the conductor from making contact with the earth and thus becoming grounded. In some cases, however, the fault may be missed on inspection. For example, the lineman may be riding on a train and fail to see the fault, on account of his vision being obstructed by smoke or steam from the locomotive. Also the fault may not be apparent. Thus

covered wire sometimes breaks inside the covering, which may support it sufficiently to prevent any additional sag that is noticeable. In such a case, if suitable measuring instruments are available, a capacity test, such as is described later in connection with testing cables, may aid in locating the fault.

278. Grounded Wires: Such faults may usually be seen by a lineman. In some cases, however, they may be difficult to find by inspection, particularly if a line passes through a considerable length of untrimmed trees, or a ground is caused by contact between a wire and a limb. Also for some reason the fault may be missed on inspection, as mentioned in the preceding article.

Under such conditions the Murray and Varley loop tests, described in *Magnetism and Electricity*, may be applied to determine the location of the fault, or the Overlap method may be used as described in the following article.

279. Referring to Fig. 188, measure with the Wheatstone bridge the resistance r, from A to earth through fault F, and the resistance r', from A′ to earth through fault F. Then if R is the resistance of the wire from A to A′, x the actual resistance of the wire from A to F, and y the actual resistance of the wire from A′ to F; x and y may be obtained from the formulas,

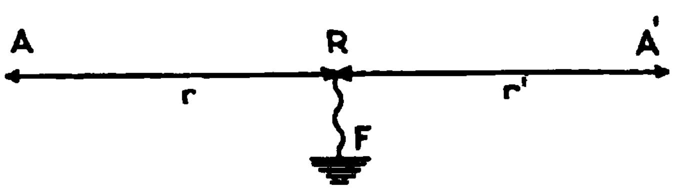


FIG. 188

$$x = \frac{R + r - r'}{2}$$

and $$y = \frac{R - r + r'}{2}$$

From either of these values the distance to the fault may be calculated.

It is necessary with this method that the ground connections at the testing stations A and A′ be good.

280. PROBLEM.—A stretch of No. 10 B. & S. G. copper line wire 5,000 ft. long was grounded somewhere along its length. In applying the Overlap method to determine the location of the fault, the resistance r was found to be 8 ohms and the resistance r', 12 ohms. How far from A was the fault located?

SOLUTION.—From the copper wire table No. 10 B. & S. G. copper wire has a resistance of 0.9972 ohms per 1,000 ft. As hard drawn copper used for line wire has a resistance from one to three per cent higher than soft drawn wire

the resistance per 1,000 ft. will probably be nearer 1.02 ohms. Assuming the latter value, the resistance of the wire in question is 5 x 1.02 ohms, or $R = 5.1$ ohms.

From the problem $r = 8$ ohms and $r' = 12$ ohms. Substituting these values in the first formula, we have

$$x = \frac{5.1+8-12}{2} = 0.55 \text{ ohms.}$$

Then, since this is the resistance from A to the fault. the distance D may be found from the proportion,

$$D : 5{,}000 :: 0.55 : 5.1;$$

$$\text{or} \quad D = \frac{2750}{5.1} = 539 + \text{ft.}, \quad \textit{Ans.}$$

281. Crossed Wires: Faults of this kind may usually be determined by inspection as in the preceding cases. If they are not apparent, as might be the case if the conductors in twin wire became crossed, the location may be determined, as in the case of grounded wires, by applying either the Murray or Varley loop tests. Another test, known as Ayrton's method, which may be used when good grounds can be obtained, is as follows.

282. Arrange the connections as shown in Fig. 189, forming virtually a Wheatstane bridge, in which one of the wires, N, forms one of the arms. Now with $a=b$ adjust r until a balance is obtained, when r will be equal to $x + y$.

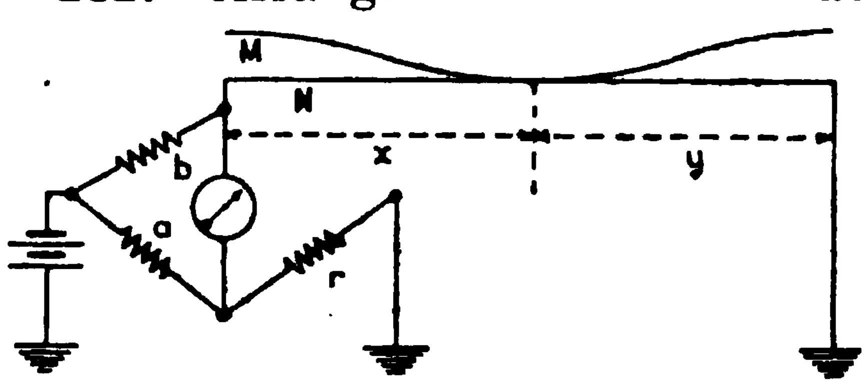


Fig. 139

Now connect the battery to wire M, instead of to the earth, as shown in Fig. 190, and adjust a until a balance is obtained.

$$\text{Then} \frac{x}{x+y} = \frac{b}{b+a}$$

$$\text{but } x+y=r$$

$$\text{therefore } x = \frac{b \times r}{b+a}$$

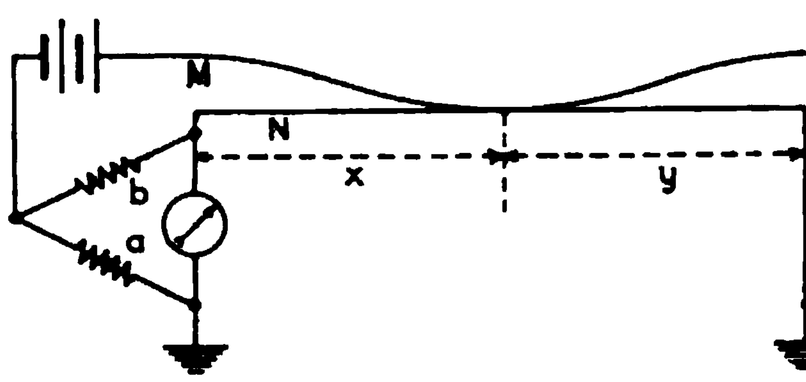


Fig. 190

283. Problem.—Two No. 10 B. & S. G. wires, each 4,400 ft. long, were crossed at some distance D from a certain point. By Ayrton's method, with the testing instruments arranged as in Fig. 189, a value of 4.5 ohms was obtained for r. With the instruments arranged as in Fig. 190, the value of a was found to be 50 ohms and that of b, 100 ohms. Find the value of D.

Solution.—From the problem $r = 4.5$ ohms, $a = 50$ ohms, and $b = 100$ ohms. Substituting these values in the formula, we have

$$x=\frac{100\times 4.5}{100+50}=3 \text{ ohms.}$$

The distance D may now be determined by the proportion

$$D : 4400 :: 3 : 4.5;$$

or $$D=\frac{3\times 4400}{4.5}=2{,}933 \text{ ft., } Ans.$$

HIGH TENSION LINES

284. For a line of given length the energy loss, due to resistance, varies with the square of the current. Therefore, if a given amount of energy is to be transmitted, it is evident that the loss may be quartered if the voltage is doubled, etc.* Consequently, when energy is to be transmitted any considerable distance, such as a mile or more, it is economical to use high voltages, varying from 500 volts in the case of shorter lines to 60,000 or more in the case of longer lines. In signal work however, the voltages used rarely exceed 2,200 volts.

285. As insulating coverings for high voltages have considerable thickness and often require the use of a lead sheath, high tension lines carrying 10,000 volts or more are, in almost all cases, composed of bare conductors supported on special insulators,

Fig. 191

*See **Magnetism and Electricity**,—*Electrical Work, Power, and Energy.*

and many lines operating at voltages below 10,000 volts, also use bare conductors. When insulating coverings are employed, they are generally of the weatherproof type.

286. Wooden poles are extensively employed for supporting high tension lines, but steel poles and towers are used to some ex tent, as they permit the employment of longer spans and may be made of practically any desirable strength.

MATERIALS OF CONSTRUCTION

287. Much of the material used for ordinary pole lines, which has been described previously, is also used in high tension work.

288. **Poles:** Wooden poles, when used for this class of work, are generally specially heavy, since very substantial construction is required to insure that there will be no interruption in the supply of energy transmitted by the line. Cedar poles are used in the majority of cases.

Fig. 192

289. Fig. 191 shows one of the several types of steel poles which are in use. It is constructed of steel angles joined by lattice work. Fig. 192 shows a steel tower of similar construction, except that tension rods are used in place of lattice work in the lower sections.

290. **Cross-arms:** When wood cross-arms are used, they are generally of the standard section or heavier. They are usually

treated in some way, such as by painting, boiling in linseed oil, or dipping in creosote, to preserve them. Steel cross-arms are frequently employed, when steel poles or towers are used, one type being shown in Fig. 192.

291. Insulators: Insulators for high tension lines are made of both glass and porcelain, and sometimes of a combination of both these materials. Many forms are in use, some typical forms being shown in Figs. 193-196.

Fig. 193

Fig. 194

292. Pins: Larger insulators and longer spans require the use of larger and stronger pins than those used for ordinary work.

Fig. 195

Fig. 196

Both wood and iron or steel pins are used, some of the forms being shown in Fig. 197.

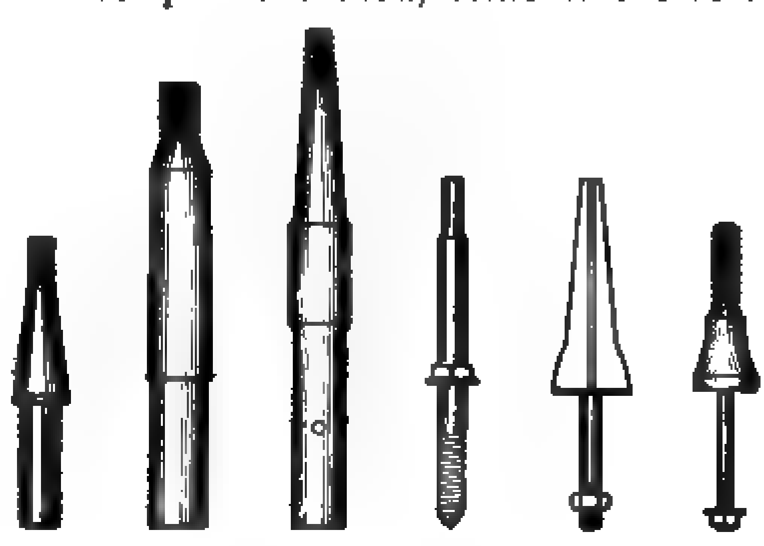


Fig. 197

293. Lightning Arresters: Four types of lightning arresters are in general use. These are the *horn*, the *multigap*, the *water-jet*, and the *electrolytic*.

294. **Horn arresters,** which have been described previously* are frequently employed in connection with arresters of other types.

295. A type of *multigap arrester* is shown in Fig. 198. In this

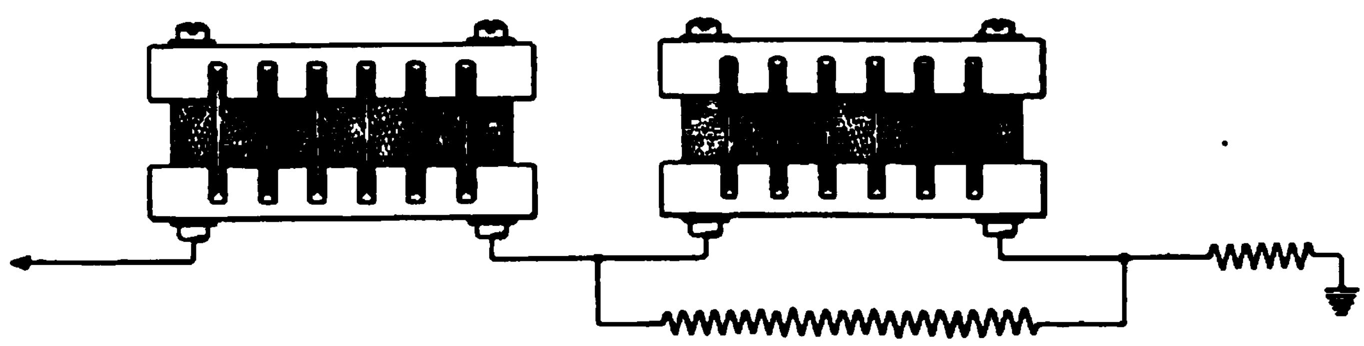


FIG. 198

arrester the path from the line to the ground is by way of a series of air gaps between cylinders of metal mounted in a porcelain block. The metal of which the cylinders are composed aids in extinguishing the arc, probably by the production of a non-conductive oxide, when vaporized by the passage of the arc; or on account of the chilling effect exerted on the arc by the metal cylinders.

A resistance is generally placed in series with the spark gaps to aid in reducing the line current following a discharge, and in some cases resistances are also placed in parallel with a portion of the spark gaps.

296. The **water-jet** or **tank lightning arrester** consists of a tank of water which is connected to the line, and which is provided with one or more jets from which water flows in a continuous stream into another tank or tray, which is grounded. The resistance of ordinary pure water is so great, that the normal voltage causes only a little current to flow to the ground by wayof the water jets. Arresters of this type are sometimes placed between horn arresters and the ground.

297. The **electrolytic** or **aluminum cell lightning arrester,** Fig. 199, is a recently developed type. It consists essentially of a series of aluminum pans or trays, each of which is partially filled with electrolyte, the pans or trays being so

*See Magnetism and Electricity.

shaped that they nest together, so that the bottom of each dips into the electrolyte contained in the pan next below. The pans are held apart at the proper distance by suitable insulators. The apparatus is enclosed in a tank or jar filled with oil. The lower pan is grounded and the upper one connected to the line, a horn arrester often being placed between the electrolytic arrester and the line as shown in Fig. 200.

298. This arrester owes its action to the formation of a hydroxide film on the surface of the aluminum. For a single cell, namely two adjacent pans and the intervening electrolyte, the film opposes a high resistance to the passage of current up to a pressure of 420 volts. Above that pressure the film opens and the resistance is greatly decreased, allowing a large current to flow. When the pressure decreases below 420 volts again, the film reforms and the current is decreased to a small value. Each cell is designed to operate normally at 300 volts, and by placing a suitable number of cells in series, an arrester can be constructed to operate on practically any required voltage.

Fig. 199

Fig. 200

INSTALLATION

299. Wooden poles, cross-arms, pins, and insulators are erected for high tension lines in the same manner as for ordinary lines. High tension lines, however, generally carry only a few conductors, and often require a different arrangement of the pins and insulators on the cross-arms. Fig. 201, and the following

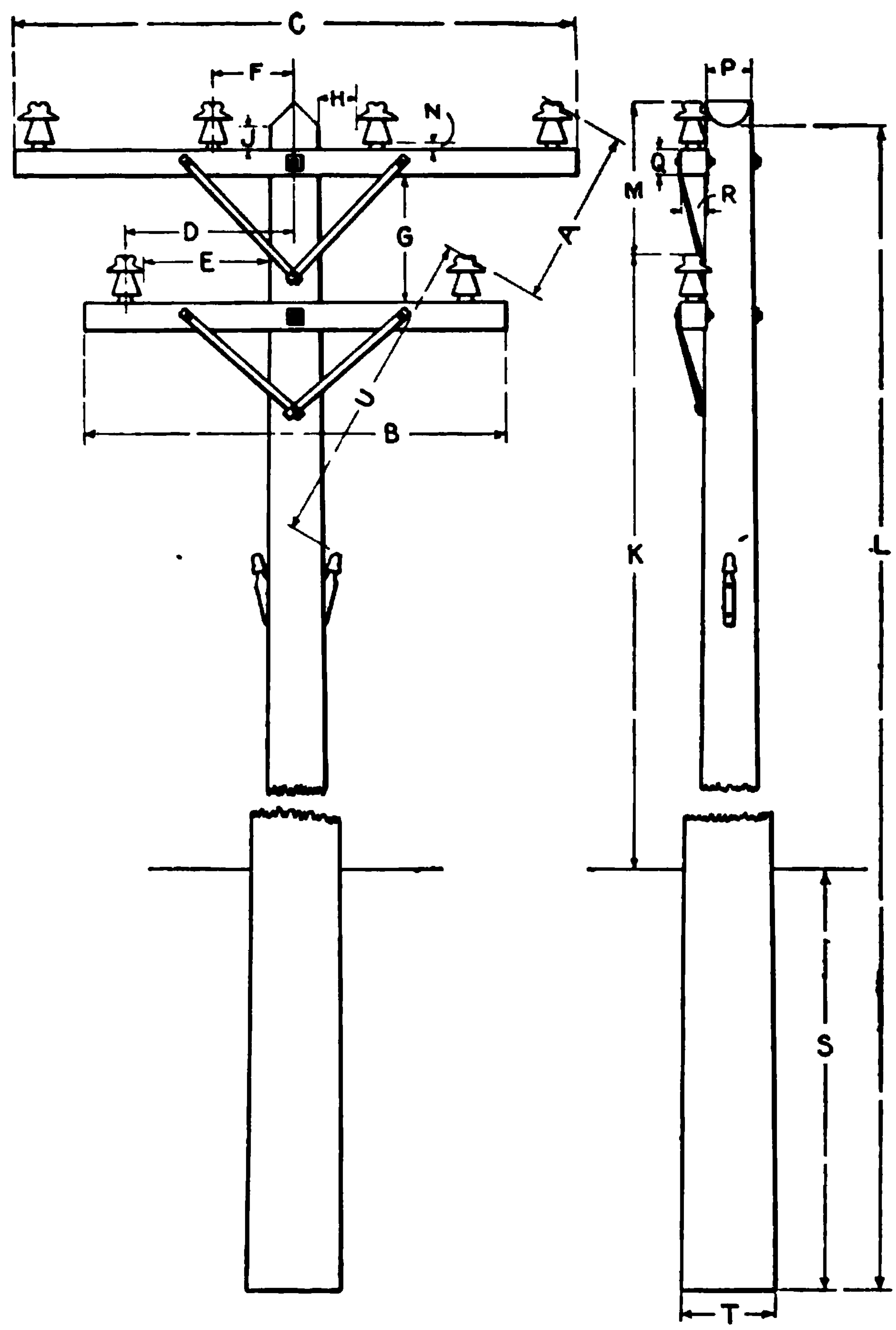


Fig. 201

table referring to it, gives the general arrangement and dimensions of high tension lines operating at pressures from 12,000 to 22,000 volts. The brackets placed below the cross-arms are for the purpose of carrying a telephone line.

Voltage	A	B	C	D	E	F	G	H	J	K
12000	24″	84″	84″	24″	17″	12″	16½″	5″	4″	32′
12000	30″	72″	96″	29″	—	14″	21″	—	—	22′
15000	30″	61″	96″	26½″	—	9″	27″	—	6″	32′
22000	30″	68″	99″	—	30″	15″	24″	15″	9″	27′

Voltage	L	M	N	P	Q	R	S	T	U
12000	40′	21″	3″	8″	4¾″	3¾″	6′	16″	54″
12000	30′	26″	—	6″	4¾″	4¾″	5′	—	—
15000	40′	31¼″	—	7″	4½″	3½″	6′	16″	10′
22000	35′	30″	—	6″	4″	4″	6′	—	10′

When steel poles or towers are used they are securely fastened to concrete foundations. The method of installing such poles and towers and of attaching cross-arms depends largely on the type of construction used.

300. Testing Insulators: High tension insulators are generally inspected for defects, such as cracks, bubbles, pits, and defects in the glaze of porcelain insulators, and in some cases are tested electrically before they are accepted. Electrical tests consist in subjecting the insulators, for a certain period, to a voltage higher than that at which they are to be operated, such as double the normal operating voltage.

301. Tying: The wires are attached to high tension insulators, either at the side, as in the case of ordinary insulators, or to the top, the latter method being desirable for heavy conductors.

Fig. 202

Fig. 203

Methods of tying applicable to the first case have been described previously. Figs. 202 and 203 show methods of tying where the

FIG. 204

wire is placed on the top of the insulator.

302. Cradles: As in the case of low tension lines, these are devices to prevent damage on account of falling wires.

A method of protecting high tension lines, where they pass below low tension lines consist in running grounded wires or strands, both above and below the high tension wires, in such a manner that a low tension wire in falling, must strike a guard wire and thus be grounded, before it can come into contact with a high tension wire.

In some cases of particular importance, where special security is desired, as at a railway crossing, a bridge may be built to carry the high tension conductors as shown in Fig. 204.

303. Other methods, which may be combined and used at the same time if desirable, consist in the use of extra strong double armed poles on either side of the crossing, double ties at insulators, short spans, extra high poles so that a wire can do no damage, even if it breaks, and a grounded net of wires placed below high tension wires, as illustrated in Fig. 185.

304. Entering Buildings: Figs. 205 and 206 show two methods of carrying high tension wires through the walls of buildings. The principal requirement is to have sufficient space around the conductors. For less than 10,000 volts, long porcelain tubes placed in the walls, with a slight downward slope toward the outside, answer very well, the wires being attached to insulators placed on each side of the wall. Higher voltages, however, require better insulation. The method shown in Fig.

FIG. 206

205 uses a 24 in. tile set in the wall, in the center of which the conductor is supported by insulators. One end may be closed with a glass plate as shown, if it is necessary to keep out the cold. The construction in Fig. 206 is good for cold climates. The slab in the center of the opening is of marble, measuring 24 in. square by 2 in., through which a 2 in. by 24 in. glass or porcelain tube is passed. The conductor passes through this, being supported on either side by insulators, as in the first method.

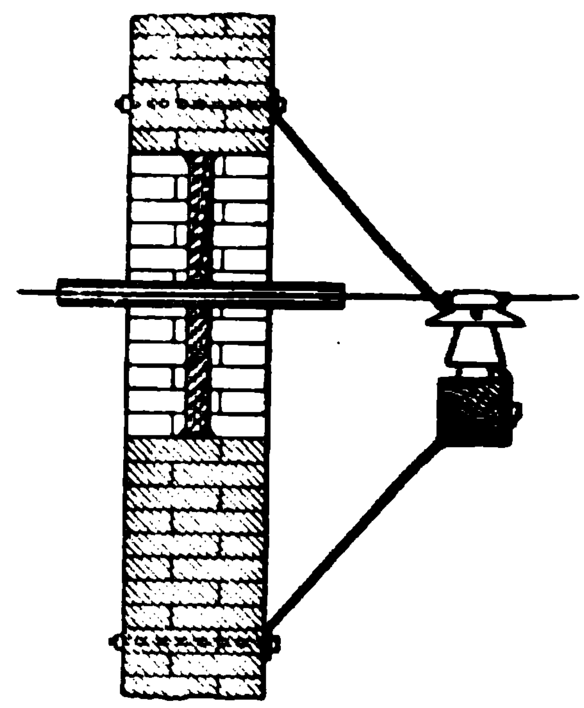


Fig. 206

305. Lightning Protection: Lightning arresters for high tension work are generally installed at power stations and sub-stations. They are sometimes installed in the stations and sometimes in separate fire proof buildings. In some cases they are installed along the line, for instance at each end and at the middle of the line, or at points dividing the line into four equal parts, etc.

In most cases choke coils are placed in series with the line.

Ground connections are usually made by the same methods that have been described.

306. Overhead ground or guard wires, as mentioned in connection with low tension lines, are sometimes installed above high tension lines, to protect them against lightning discharges. Such wires must be sufficiently strong so as not to break and fall across the line wires.

307. Splicing: When solid wires are used for high tension work, the methods of splicing already described are applicable. Stranded wires are spliced, either by weaving the ends together and soldering, or by soldering them into a copper connecting sleeve. Another method is to use a mechanical coupling or connector, such as the *Dossert*, Fig. 207,

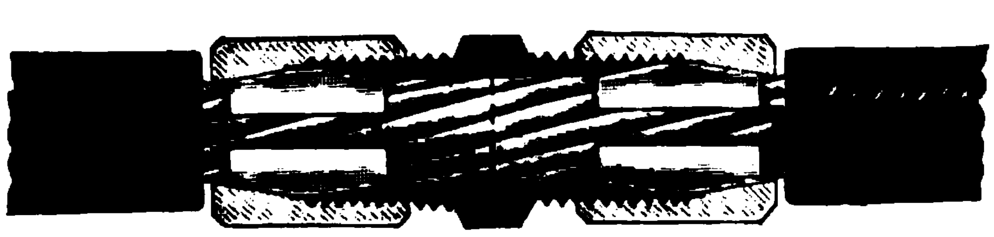


Fig. 207

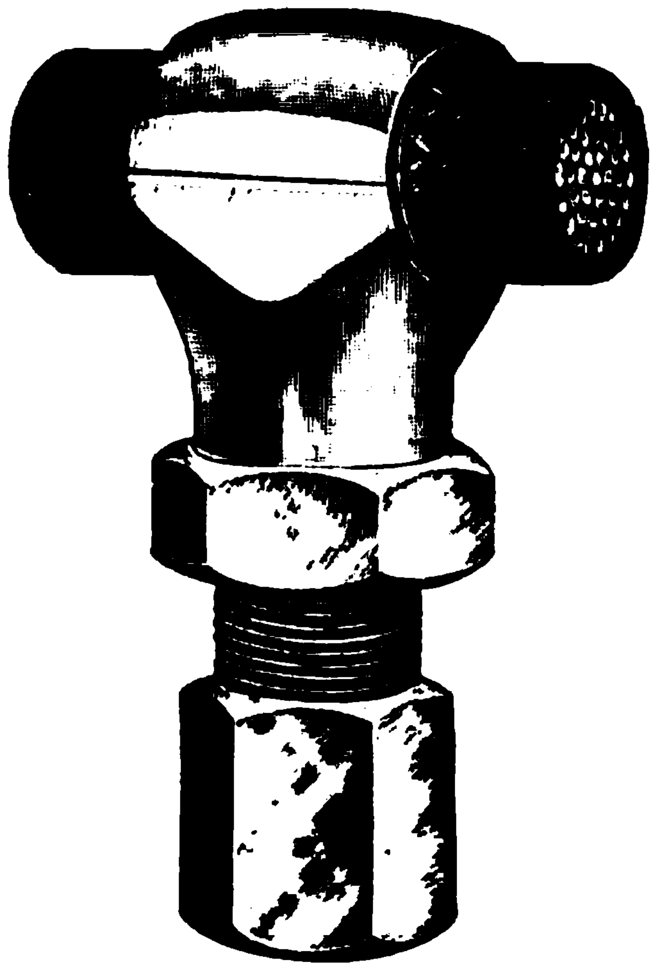


Fig. 208

which does not require the use of solder. Fig. 208 shows a tap made by the Dossert method. Connectors of this type may also be used for solid wire.

MAINTENANCE

308. The location of most troubles on high tension lines are determined by inspection. For this purpose lines are usually patrolled at different intervals, varying from every day to only a few times a year, and in some cases only when trouble occurs.

309. Before starting work on a high tension line, it should be ascertained whether or not the line is dead. This is usually done by communicating with the operator, stationed at the point where the switches controlling the line are located, and waiting until advice is received from this operator that the line is dead, and tagged to indicate that work is being done upon it.

310. Suitable precautions should also be taken to insure that a line remains dead while working on it. Such precautions consist in grounding, short-circuiting, or both grounding and short-circuiting the line. Grounding is generally done by means of a certain type of bamboo pole, which is provided with one or more hooks connected to a wire. The wire is first grounded, after which the hooks are made to engage with the line wires.

EXAMINATION QUESTIONS

(1) (*a*) What is the purpose of a guy? (*b*) What device is sometimes used in place of a guy?

(2) (*a*) What name is given to a guy which is run from the top of one pole to the butt of the next pole? (*b*) How should a tree trunk be protected when a guy is placed around it?

(3) What is meant by the term dead end?

(4) (*a*) Draw a sketch of a six pin cross-arm showing how the wires should be placed on the insulators when the line is straight. (*b*) Draw a similar sketch showing the arrangement of wires when the line is curved.

(5) By what means are line wires fastened to insulators?

(6) What are spider wires?

(7) (*a*) What means are usually employed to connect hard drawn copper wires? (*b*) Name three joints that may be used in joining soft drawn copper wires.

(8) What is a tap? Illustrate your answer by a sketch.

(9) (*a*) Of the different methods of soldering joints, name two that are considered the best. (*b*) What is the purpose of soldering flux?

(10) (*a*) In joining rubber covered wires what kind of tape is used next to the wire? (*b*) What kind of tape is used to finish the joint?

(11) What is a transposition?

(12) Give the general name that is applied to devices whose purpose is to prevent wires from falling where lines cross each other.

(13) Give two methods by which a line may be protected from lightning discharges.

(14) What means may be used to improve a ground if its resistance is too high?

(15) Name two methods of testing by means of which a cross may be located.

(16) Why are high voltages used on long transmission lines?

AERIAL CABLE LINES

311. Since cables have the advantage of being better protected from accidental grounds and other disturbances than open wires, their use is sometimes considered advantageous, even though faults are generally more difficult to locate; also when the wires of a pole line would exceed a certain number, it is usually considered better to employ an aerial cable in place of them.

MATERIALS OF CONSTRUCTION

312. Various types of cables are employed for aerial work. The cables generally used in signal work, however, are made of rubber covered wires, the outside of the cable being protected by layers of tape covered with braid.

313. Cable is wound for transportation on strongly built *wooden reels*, Fig. 209. After the cable is in place on the reel, strips of wood, commonly known as *lagging*, are screwed or nailed around the outside, to prevent injury to the cable.

314. In constructing aerial cable lines much of the material already described is used. Certain special devices are required, however, these being described in the following articles.

Fig. 209

315. Messenger Wires: Cables are not considered sufficiently strong to permit them to be stretched from pole to pole like open wires. They must be supported, therefore, by some other means. The method commonly employed is to string steel wires, either solid or stranded, from pole to pole and hang the cables from them. These wires are known as **messenger, suspension,** or **carrier wires.**

NOTE.—The School of Railway Signaling wishes to thank the Standard Underground Cable Co. for information furnished in regard to cable work.

316. Nos. 9, 8, and 4 B. W. G. double galvanized solid steel wires are employed for wire messengers, stranded wires or cables measuring from $\frac{5}{16}$ to $\frac{1}{2}$ in. in diameter, being used if stronger messengers are required. Stranded wire for this purpose should consist of seven double galvanized steel wires twisted together. The following table gives the weights and strengths of messenger wires and cables.

STRENGTH OF MESSENGERS

Size	Weight in Lbs. per Ft.	Breaking Weight in Pounds	
Steel Wire			
No. 9 B. W. G.	.058	1720	
No. 8 B. W. G.	.072	2138	
No. 4 B. W. G.	0.149	4450	
Stranded Wire		Ordinary Steel	Special Steel
$\frac{5}{16}$ in.	0.21	3300	6600
$\frac{3}{8}$ in.	0 30	4700	9400
$\frac{7}{16}$ in.	0.37	6000	12000
$\frac{1}{2}$ in.	0.51	8320	16640

317. Messenger Wire Supports: If the number of cables comprising the line will never exceed two, the messengers may be supported by galvanized iron **messenger clamps,** Fig. 210, which are fastened to the sides of the poles with lag screws or bolts. For more

Fig. 210

Fig. 211

than two cables, particularly if large, **cable arms,** Fig. 211, may be used. These are angle iron cross-arms made of 4 in. by 3 in. angles, about 32

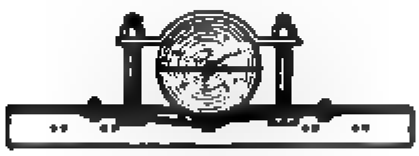


Fig. 212

Fig. 213

in. long, bolted to the pole. They are drilled for two cross-arm braces, which are attached to the pole above the arm. When the strain is severe a *stirrup* may be used to support the lag screw which fastens the braces to the pole, as shown in Fig. 213, and in addition a strap may be put around the pole as shown in Fig. 212. For very heavy strains two angles may be placed back to back on opposite sides of the pole.

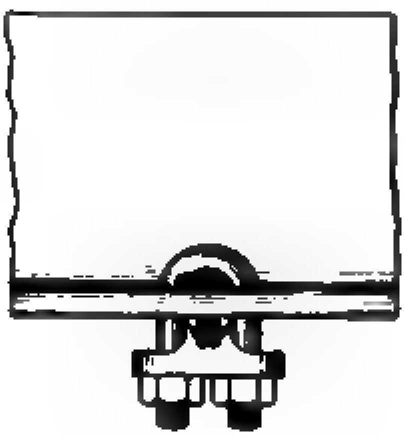


Fig. 214

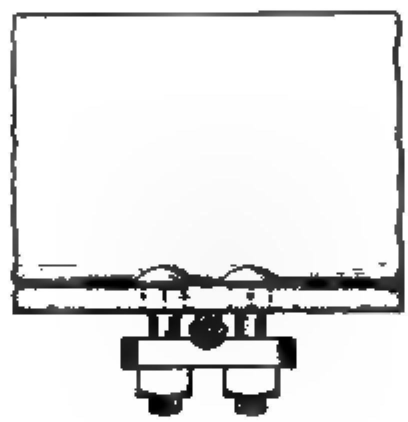


Fig. 215

Fig. 213 shows another form of cable arm in which a regular cross-arm is placed in the angle iron. Four cross-arm braces are used and attached to the pole below the arm.

318. The messengers are clamped to the cable arms by U-shaped clamps as shown in Fig. 214, or two carriage bolts may be used in place of the U bolt, as shown in Fig. 215. In either case the threaded ends of the bolts hang down, and the messengers are clamped between the under side of the cable arm and straps held by the nuts.

Fig. 216

319. Cable Hangers: Cables are suspended from their messengers by means of **cable hangers.** These are made in many

forms. Fig. 216 shows what is known as a **marline hanger,** the cable being attached by a marline loop to a galvanized steel hook passing over the messenger.

320. *Marline* is cord or twine with a diameter of from $\frac{1}{8}$ to $\frac{3}{16}$ in. It is generally *tarred* for line work to give it a longer life.

321. Fig. 217 illustrates a hanger in which the marline is replaced by a zinc strap, and Fig. 218 shows a malleable iron

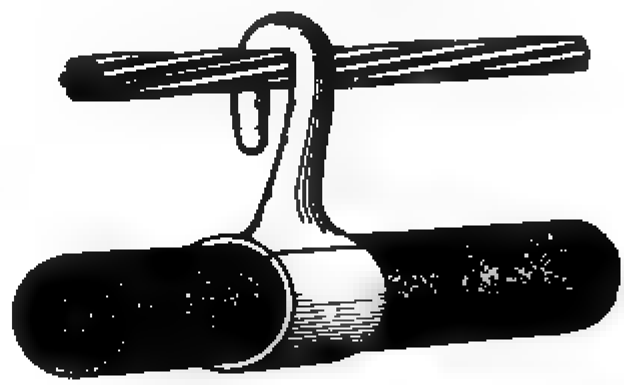


Fig. 217 Fig. 218

hanger, the latter type requiring special pliers to close it on the cable.

322. Terminal and Junction Boxes: At the point where a cable ends a **terminal box** is frequently placed, in which connections are made to the wires leading to the cable and which may contain lightning arresters if employed. A similar box may be used at the junction between cables, and where a branch or loop is taken off from such cables. When used in this manner it is known as a **junction box.** Junction boxes may also be placed at intervals along a cable to provide a convenient means of access to the conductors.

A *terminal* or *junction box,* one form of which is shown in Fig. 153, is made of iron or wood, built so as to be weatherproof. It contains binding posts, connected to short strips of brass or copper, known as terminal strips, by means of which the various wires may be joined. These are mounted on the back of the box or on strips of suitable material, so as to be insulated from one another. The box may also contain panels of wood or fiber with holes through them to aid in distributing the wires. Such boxes are also called **cable pole boxes** or **houses.**

323. Pole Seats: When a junction or terminal box is mounted near the top of a pole, a **pole seat** may be provided as shown

in Fig. 219, in case it is necessary to do considerable or frequent work in the box.

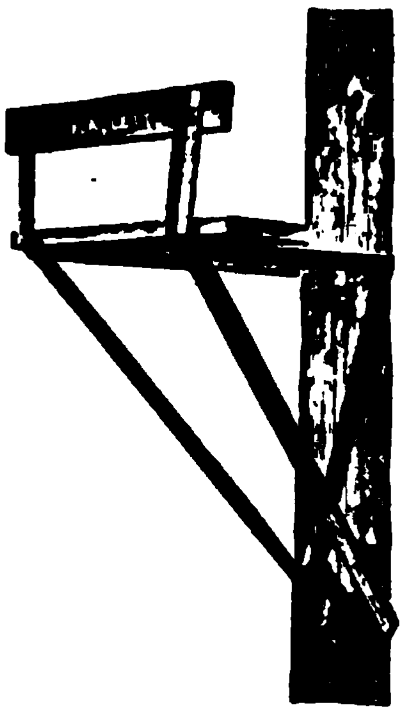


Fig. 219

CONSTRUCTION TOOLS

324. Among the special tools used in the construction of aerial cable lines the following are the most important.

325. Reel Stands and Jacks: In order to unwind the cable from a reel, it is necessary to pass a shaft through the center of the reel, and then support the shaft so that the reel is raised above the ground. The **reel jack** or **stand,** shown in Fig. 220, is a convenient device for doing this.

326. Another method, which also provides a means of *moving* the reel, is to place a large wheel at each end of the shaft held in place by removable collars, the diameter of the wheels being

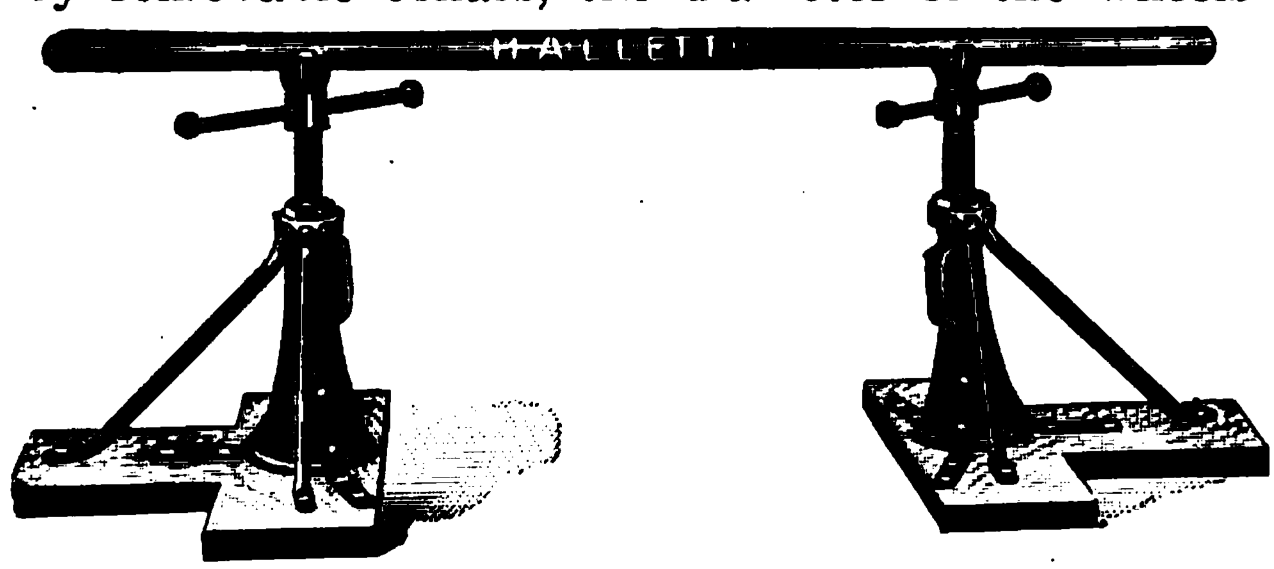


Fig. 220

great enough to raise the reel clear of the ground. A frame passing around the wheels is removably attached to the ends of the shaft, and a short wagon tongue connected to it to aid in moving the device.

327. Cable Grips: These are used as a means of attaching a pulling rope to the end of a cable. Various forms are employed, among which is the type shown in Fig. 221, which is attached to the cable by screws, and the type shown in Fig. 222. As the pull increases

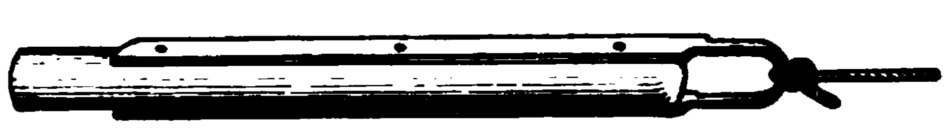


Fig. 221

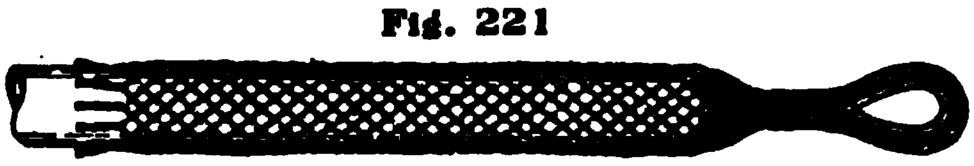


Fig. 222

on the eye of this latter grip, the net tends to elongate and reduce in diameter, thus gripping the cable, the security of the grip increasing with the degree of pull.

328. Winches and Capstans: Power for pulling cables into place is often obtained from some form of a **winch,** Fig. 223, or **capstan,** Fig. 224. Such devices may be driven by man, horse, steam, or electric power. Those shown are arranged to be operated manually.

Fig. 223

329. Cable Trolleys or Rollers: These are devices, Fig. 225,

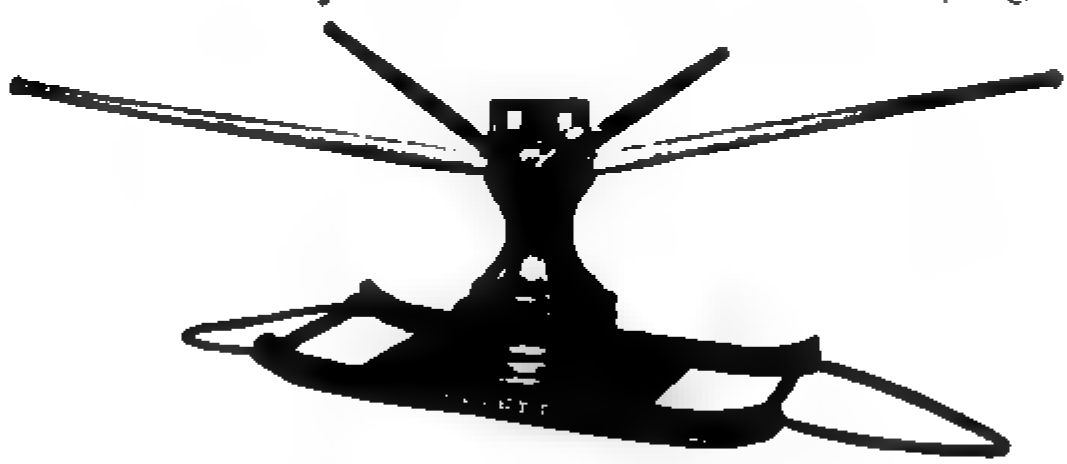


Fig. 224

arranged so that they may be attached to messenger wires, and

Fig. 225

which are provided with grooved wheels over which cables may pass in the operation of stringing them.

330. Jig Reels: Devices of this type, Fig. 226, also called **cable winders** and **spinning jennies,** are used to wind a continuous serving of marline around the cable and its messenger, thus

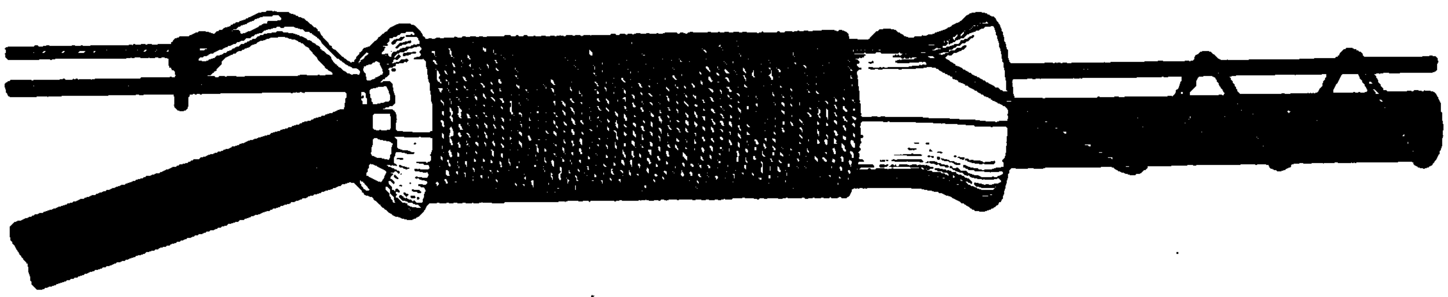


Fig. 226

fastening them together. They consist of wooden bobbins made in halves, with a hole through the center large enough to allow the cable and messenger to pass through it. They are lined with copper to make them wear well.

331. Messenger Cars: In case it is necessary to get at some portion of a cable between poles, a **messenger car** or **cable car,** one form of which is shown in Fig. 227, is used. This car consists of two trolleys or grooved wheels attached to a framework of iron rods supporting a seat. The trolleys run on the messenger wire and the car is pulled to any desired position by a rope.

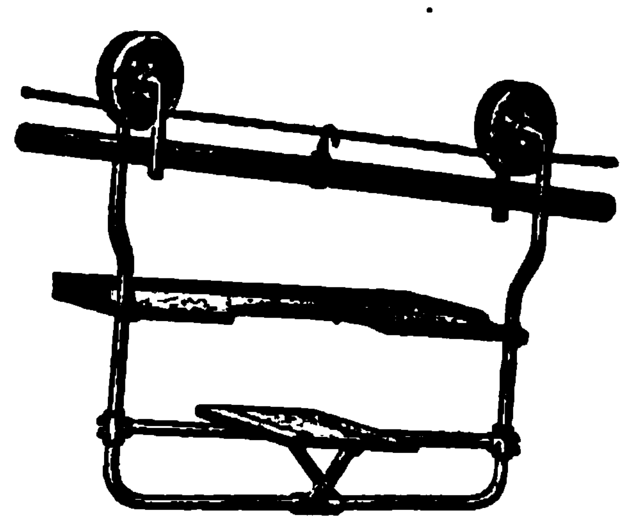


Fig. 227

INSTALLATION

332. Reinforcing the Pole Line: Previous to pulling messenger wires upon a pole line, the entire line must be firmly anchored and guyed. At corners and at terminal poles special care should be taken to reinforce the line, so that sufficient strength is secured to resist the strain introduced by the cables. The strength of guy wires at terminal poles and corners should be double the strength of messenger wires, and they should be pulled up and securely fastened before the messenger is strung. In some cases, where cables are strung on poles carrying open

wires and the span between poles is too long, an *intermediate post* may be erected at the center of each span to support the messengers and cables.

333. Attaching Messenger Wire Supports: Messenger supports or clamps, as shown in Fig. 210, are bolted to each pole about one foot below the lowest cross-arm. The clamp is placed with the axis of the groove parallel to the direction of the line. The clamps for a given cable are usually bolted on the same side of all poles, so that the messenger may be strung in as straight a line as possible. They may be attached previous to stringing the messenger, or they may be bolted in place at the time the messenger is installed. Fig. 228 shows a method of supporting a messenger wire with a bolt and guy clamp, in case no regular messenger clamps are at hand.

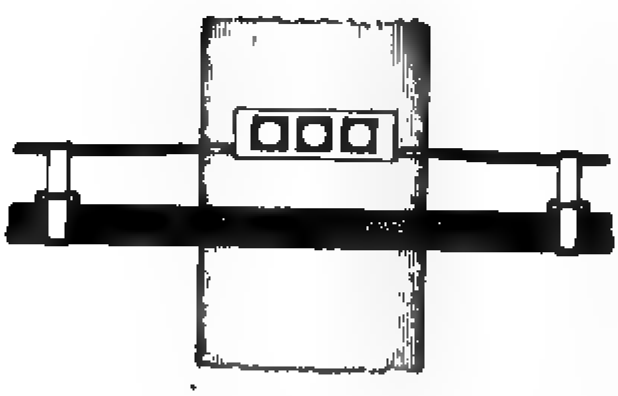


Fig. 228

334. Angle iron cable arms when used are bolted in the lowest gain on each pole, and braced or strengthened according to conditions, as already described.

335. Stringing Messenger Wires: After the messenger supports are properly bolted into place, the messenger is drawn from its reel, lifted up to its supports, and clamped temporarily but tightly. One end is then fastened securely to a suitably guyed pole, known as an **anchor pole**, by wrapping it from one to three times around the pole, and then bringing the end back and securing it with guy clamps, so as to form an eye about 8 in. long. It is considered preferable to use guy clamps of the three bolt type. In case wire rope clips are used it is considered advisable to place a piece of sheet lead about $\frac{1}{16}$ in. thick between the ropes and the clip, to make the fastening more secure. If stranded wire is employed for the messenger, the free end may be allowed to project about 18 in. from the clamp, and should be straightened,

laid alongside the messenger, and served with bands of galvanized iron wire, such as No. 14 B. W. G., spaced 6 in. apart.

336. Galvanized iron strips are placed underneath the messenger, to prevent it from cutting into the pole. These are about one inch wide and 6 to 8 in. long. They are nailed vertically around the pole with a one inch space between them, before the messenger is wrapped around it. A spike or guy hook is used to prevent the messenger from slipping off the strips.

If more than one messenger terminates at a pole, they are fastened one above the other.

For an anchor pole it is considered better to use a pole, ahead of the pole at which the cable is to start, as by this method the cable pole is free from guy wires. It is also considered better not to use the messenger as a guy.

337. The tackle for tightening the messenger is now attached to the farther end. This tackle may consist of an arrangement of pulley blocks, or a winch may be used. Then, after the messenger clamps have been loosened to allow the messenger to slide freely, it is pulled to nearly the proper tension. After this has been done the messenger is cut off, leaving a sufficient length to attach it to the anchor pole. If stranded wire is used for the messenger, it should be served with two or three turns of wire on each side of the point where it is to be cut, to prevent untwisting. More power is then applied and the messenger pulled until it has the proper sag. Finally all supports are tightened permanently, and this end fastened to its anchor pole in the same manner as the first end. It is considered preferable to terminate the messenger on the pole beyond the one upon which the cable is to terminate.

338. In case more than one messenger is to be tightened, after the first has been pulled to the proper tension, it is clamped at its supports. It is not fastened at the anchor pole, however, as it will become somewhat slack when the second is pulled up, and this slack must be taken up before the first one is permanently fastened. Generally after the first two messengers have both been pulled to the proper tension, they may be permanently fastened. If there are others, they may then be pulled up to the same deflection as the first two and permanently fastened.

It is possible to pull a messenger around a smooth curve, but not around a corner. At corners, therefore, the messenger must be cut and the ends fastened to the corner pole in the same manner as at an anchor pole.

339. **Supporting Capacity and Sag:** It is recommended by one authority that the strain in the messenger, due to its own weight and that of the cable it supports, should not exceed one-half the breaking strain. That is, a factor of safety of two is used. It is also recommended that the minimum sag should not be less than one per cent of the span, and that a messenger of such size be used, that with this amount of sag the strain will not exceed the value just mentioned. The sag should be so regulated, therefore, that in the coldest weather it will not decrease to less than one per cent of the span.

340. The load that a messenger will support may be determined quite closely from the formula

$$W=\frac{8Td}{L};$$

in which W = the load in pounds, T = the safe working strain in pounds, d = the sag in feet at center of the span, and L = the length of the span in feet.

341. As an example, take the case of a ½ in. ordinary steel cable strung across a span of 100 ft. In this case, using a factor of safety of two, and taking the breaking strain from the table in Art. 316, we have

$$T=\frac{8320}{2}=4{,}160 \text{ lbs.},$$

and since $L=100$ ft.,

$$d=.01\times 100=1 \text{ ft.}$$

$$\text{Therefore } W=\frac{8\times 4160\times 1}{100}=332.8 \text{ lbs.}$$

Now the weight of the messenger itself is 100×0.51 lbs. $=51$ lbs., and this value subtracted from 332.8 lbs. leaves 281.8 lbs., as the weight that the messenger will safely support, which is equivalent to a cable weighing 2.818 lbs. per ft. This does not allow for an extra load of sleet or snow or for the weight of a messenger car. Where sleet or snow are encountered or a mes-

senger car is to be used, the size of the messenger must be increased sufficiently to support the additional burden.

342. The following table* is calculated from the preceding formula, using sags equal to one per cent of the span and a factor of safety of two.

SUPPORTING CAPACITY OF MESSENGERS

Size		Span in Feet				
		80	100	120	150	200
Steel Wire		Weight per Foot of Cable that can be Supported				
No. 9 B. W. G.		0.802	0.630	0.515	0.401	0.286
No. 8 B. W. G.		0.997	0.783	0.640	0.498	0.356
No. 4 B. W. G.		2.076	1.631	1.334	1.037	0.741
Stranded Wire						
Ordinary Steel	5/16 in.	1.440	1.110	0.890	0.670	0.450
	3/8 in.	2.050	1.580	1.266	0.953	0.640
	7/16 in.	2.630	2.030	1.630	1.230	0.900
	1/2 in.	3.650	2.818	2.263	1.709	1.154
Special Steel	5/16 in.	3.090	2.430	1.990	1.550	1.110
	3/8 in.	4.400	3.460	2.832	2.206	1.580
	7/16 in.	5.630	4.430	3.630	2.830	2.030
	1/2 in.	7.810	6.146	5.036	3.928	2.818

343. As the cable is not attached to the messenger until the latter is pulled up to the proper tension, it is necessary to adjust the sag of the messenger to a value somewhat less than that desired when the cable is in place. The amount of difference to allow is generally determined from experience.

*In this table no allowance is made for sleet or snow, or a messenger car.

344. As a cable is seldom erected in the coldest weather, the deflection to allow at other temperatures, to produce a given deflection at the minimum temperature, must be obtained. This may be done as follows:

345. First the length L' of the messenger is calculated, when it has the proper sag at the lowest temperature, by means of the formula

$$L' = L + \frac{8d^2}{3L},$$

in which L and d have the same values as in Art. 340.

Then if d' equals the sag at any other temperature, and L'' equals the length of the messenger at that temperature,

$$d' = \sqrt{\frac{3L(L''-L)}{8}}.$$

L'' is obtained by multiplying L' by [*1 + (the coefficient of expansion × the difference in temperature*)]*. The coefficient of expansion for steel wire may be taken as .0000066 and for iron wire as .0000068.

Take as an example the ½ in. messenger cable previously used. Suppose the cable is to be erected at a locality where the minimum temperature is 10 deg. below zero, but that on the day the cable is to be strung the thermometer indicates 80 deg. above zero. Since the sag at the minimum temperature is to be one per cent of the span, or one foot, we have by substituting in the formulas,

$$L' = 100 + \frac{8 \times 1^2}{3 \times 100} = 100.0267 \text{ ft.}$$

$$L'' = 100.0267[1 + (.0000066 \times 90)] = 100.086$$

$$\text{and} \quad d' = \sqrt{\frac{3 \times 100 \ (100.086 - 100)}{8}} = 1.8 \text{ ft.}$$

346. Testing: Before making connections to a cable or before it is removed from the reel it should be tested for *breaks* or *crosses*. The same general method as that described in Arts. 426-430 for lead covered cables, may be followed. In making the test for *broken wires*, the battery should be connected to good wire in the cable instead of to the lead sheath.

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*See Heat and Light.

347. Stringing Cables: Following the erection of the messengers, the *reel* with the cable that is to go up first is placed ahead of the pole at which the cable is to start, and arranged either on *wheels* or *reel jacks*, so that it may turn and allow the cable to unwind. The lagging is then removed carefully, and screws or nails in the edges pulled out to prevent damage to the cable covering. The reel should be placed so that the cable will come off from the top in unwinding.

348. A *guide wire*, sometimes called a *leading up wire*, may now be run from the pole, at which the cable is to start, to the ground at a point near the reel, where it is suitably secured. The purpose of this is to provide an incline up which the cable may pass from the reel to the first pole. Following this a suitable rope, of sufficient length to extend from the reel to the pulling apparatus, is attached to the end of the cable. Attachment is made by some form of *cable grip*, and a swivel is placed between the grip and the rope. The grip should be applied so as to distribute the pulling strain as uniformly as possible over the core and covering of the cable. At the cable pole a wooden *pulley block* with a large sheave may be located, with its top just below the messenger, to facilitate running the cable. The pulling rope is supported on pulleys at each pole, and the power to pull the cable is supplied by a *capstan* or *winch*, located at the end of the stretch.

349. An inspector is usually stationed at the reel to watch for defects in the cable, and prevent any defective cable from being strung. One method for stringing cable requires, in addition to the inspector, three other men at the reel, two men at the first pole, one man at every other pole, and three men to handle the winch.

After the rope is attached to the cable, it is passed over the supporting pulleys and finally laid upon the winch to be wound up. The winch is operated so that the velocity of the rope is low, about 12 ft. per minute. As the cable starts to unreel, one man marks off the points where the *hangers* are to be attached, allowing equal spaces of about 20 in. between them. Other lengths of spaces, varying from 18 to 24 in., are sometimes used. The next man attaches the hangers to the cable at the marks,

and the third hooks every fourth or fifth hanger upon the guide wire. At the first pole one of the men guides the cable over the sheave, while the other unhooks the hangers from the guide wire and hooks them on to the messenger wire. As the hangers reach the men on the other poles, they unhook them and then hook them again as soon as they have passed the messenger supports. After the drawing is commenced, it should proceed uniformly and steadily until the entire length of cable is in position. When the end of the cable reaches the next to the last pole, a signal is given and all the men hook all hangers, so that when the cable is in place all hangers are hooked to the messenger. Finally a man may be sent over the messenger in a *cable car*, to adjust all hooks and see that they are secured so as to be safe from unhooking, and to straighten out the cable if necessary.

350. Instead of sliding the hangers along the messenger, the cable is sometimes carried in *cable trolleys* which are temporarily attached to the messenger. In this case the hangers are either hooked to the messenger when the next to the last pole is reached, or this is done by a man riding along the messenger in a cable car.

351. In place of hangers the cable may be fastened to the messenger by winding them together with marline. In this method the cable is drawn into position by means of trolleys. One end of a piece of marline is then tied to the messenger at a pole, and wound upon a *spinning jenny*, which has been placed around the cable and messenger. The spinning jenny is then pulled to the next pole by means of a rope. As it slides along the messenger the cable is drawn up into position, and fastened by the spiral wrapping of marline which unwinds.

352. Another method, used where the cable is short, consists in lashing it to the messenger with marline, the distance between successive lashings being about the same as that given for hangers.

353. At sharp bends, as in turning to extend up or down a pole, or where a splice is located, additional security should be given by lashing the cable or splice to the messenger with marline. Where a line is inclined considerably, the cable should be secured by lashing at every pole, to prevent the hangers from

sliding along the messenger.

354. Splicing: The splicing of lead covered cables will be taken up in *Underground Lines.* Joints in rubber insulated cables, protected by an outer covering of tape and braid, are made as follows:

355. First the outer covering is cut back a sufficient distance, so as to expose a suitable length of the insulated conductors, care being taken in doing this to avoid injuring their coverings. The *center* conductor of one cable end is then spliced to the *center* conductor of the other cable end, and the joint insulated by layers of *rubber tape* in the same manner that single rubber covered wire is spliced and insulated. Generally each layer of conductors in a cable has a *marked wire,* and after the center wires are joined and insulated, the marked conductor of one cable end, in the layer *next* to the center conductor, is spliced to the corresponding marked conductor in the other cable end, and the joint insulated as before. Then in this same layer, the next conductor beyond the marked conductor of one end is spliced to the next beyond the marked conductor of the other end, counting in the same direction, and so on until all the conductors are spliced each joint being insulated before the next conductors are spliced.

The wires should be cut so that the joints will come at the proper place, the joints in adjacent wires being *staggered,* in order that the diameter of the cable may not be increased unnecessarily at the splice. On account of the extra length required for this arrangement, sufficient allowance must be made in cutting the cable, cables having a large number of wires requiring a longer splice than those having only a few wires.

After the individual conductors are spliced a covering of *friction tape* is placed over all, the tape extending over the outer braid for about 2 in. Finally the splice may be given a coat of P. & B. compound.

356. Terminal and Junction Boxes: These boxes are bolted to the *cross-arms, pole,* or to a short *connection post* located near the pole. In order to work at boxes which cannot be reached from the ground, *pole seats* must be provided to support the linemen. It is convenient, however, to place the boxes on the

pole at such a height that they can be reached from the ground, the cables being carried down the pole to the box. One method of supporting the cables on the side of a pole, when they are carried down to a box, is by means of *porcelain insulators* with large grooves, as shown in Fig. 229, the cables being tied in place with marline.

The cable is carried into the box at the bottom, and its wires separated and distributed to the binding posts. When taped or braided cables are used this is done as shown in Fig. 230.

357. If the wires leading from a junction box are to continue as open wires run on insulators, the rubber covered wires leading from the box are generally distributed up the pole and along the cross-arms by the use of *spider wire cleats*, *bridle rings*, or *trunking*, etc.

Fig. 229

Another method of doing this is shown in Fig. 231. The wires are carried through the sides of the junction box in porcelain bushings, a metal shield being provided to prevent the entrance of water.

358. Loop and Branch Lines: Aerial cable is often

Fig. 230

employed for loop and branch lines. If the main line is also an aerial cable, connections between the main line and the loop or branch are made in a junction box. The loop or branch cable is run from the junction box to its destination supported by a messenger, in the same manner that the main line is run. In some cases, where the distance is very short, no messenger is required, the cable being sufficiently strong to support itself. In such cases the ends may be supported by lashing

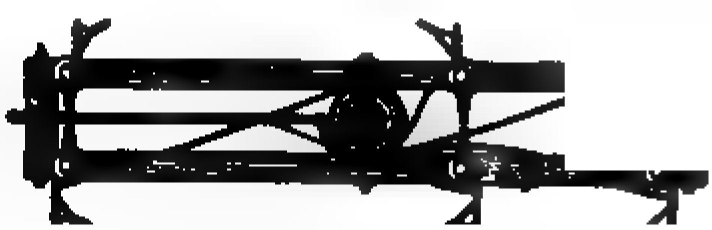


Fig. 231

them with marline to an eye or hook bolt, or other support.

Fig. 232

359. If the main line is composed of *open wires*, spider wires may be run to a junction box, where connections are made to the cable forming the loop or branch. In some cases, one of which is shown in Fig. 232, the junction box is not

used, the wires of the cable being connected directly to the line wires. Another method used for short distances, which does not require a junction box, is to simply bunch the spider wires together in a hand made cable.

360. Hand Made Cables: There are several methods of making *hand made cables.* Thus the wires may be bound together with tape, or they may be wound or tied with marline as shown in Fig. 233. Such cables may be supported by a messenger if necessary, although for short distances the messenger is usually omitted, the cable being strong enough to support itself. A method of increasing the strength of the cable, when no messenger is to be used, is to include in it a weatherproof iron or steel wire, which is suitably fastened at the ends and serves to support the cable.

Fig. 233

361. Lightning Protection: Lightning arresters are often installed in terminal or junction boxes, to protect the line when it changes from cable to open wire construction, and usually when it is connected to a branch or loop, as shown in Fig. 230. This illustration also shows the ground wire carried above the top of the pole for further protection against lightning discharges. In addition the messenger wire is often grounded for this purpose.

362. Entering Buildings: One method of bringing a cable into a building is shown in Fig. 234. The cable is supported between the pole and the building on a messenger, and passes through the wall of the building in a sheltered place to prevent

Fig. 234

the entrance of moisture. The messenger is secured to the building either by passing it through a hole in the wall and wrapping it around a beam or joist, fastening the ends with clamps; or an eye bolt, employing an O. G. washer if there is considerable strain, is passed through the wall and the messenger fastened to this. At a point a few inches from the wall, the cable is securely lashed to the messenger with marline, in such a manner as to prevent it from slipping away from the building. It is then bent down into a drip loop after which it passes through the wall. In place of using a drip loop the cable is frequently carried from the line to the building on an upward incline, so that water tends to run away from the entrance, this method being particularly desirable when several cables are bunched together and enter a building at the same point.

Another method is to carry the cable down the pole and to the building in trunking. The method of connecting the trunking to the building will be described later.

MAINTENANCE

363. Cables, while less subject to disturbances than open wires, are sometimes damaged by causes such as lightning discharges, bullets, etc., which may injure the insulation and produce breaks or crosses. In general, injury to cables is more difficult to discover by inspection, than in the case of open wires, since the condition of the outer insulation is about all that can be observed. Thus injury due to bullets may sometimes be discovered by the frayed appearance of the braid where cut by the bullet.

364. If junction boxes are placed at frequent intervals, the section of cable between every two boxes may be tested with a voltmeter or other instrument and in this manner the fault located in a particular section. The method of locating a *break* is to connect a battery to the *faulty* wire and a *good* wire at a junction box or other convenient place. Then the voltmeter will give an indication when connected to the *same* wires, until the section containing the break is reached. After this section is passed the needle will not be deflected. In the case of a *cross* the same method may be employed, if the wires are *disconnected* at

the point where the voltmeter is attached, and only the portion between the battery and voltmeter tested.

After the section containing the fault is found, the outer covering of the cable may be opened at some point along this section, such as an old splice, if there is one, and each portion again tested, the operation being repeated, if necessary, until the fault is found. At the point where the outer braid is removed, connections to the different conductors may be made by spreading them apart, and pricking through the insulation with a needle pointed instrument, thus avoiding the necessity of removing their insulation.

365. The general procedure for making *insulation resistance tests*, and for locating *crosses* and *grounds* by the Varley and Murray Loop tests has already been described. In making tests of insulation resistance, it is very important that the lead wires from the instrument to the cable be perfectly insulated from each other. Otherwise a serious error may be introduced into the measurements. In locating crosses and grounds by the Varley and Murray loop tests, proper allowance should be made for the resistance of the wires leading from the instruments to the cable. One method is to make these wires the same size as the wires under test, so that they may be considered as an extension of the cable wires. Another method is to make them short and of sufficient size, so that their resistance may not be appreciable.

366. Cables are frequently provided with one or more spare wires, so that in case a wire develops a fault, it may be disconnected and a spare wire substituted in its place.

367. If a cable provided with marked conductors contains an old splice, care should be taken, before making connections in accordance with the markings, to determine that the proper conductors are joined at the splice.

368. Practically the only care that a braided cable requires, other than seeing that the poles, messenger, and other accessories are in the proper condition, is to paint it at intervals of about two and one half years. *Stockholm tar* is recommended for this purpose, as it is said to remain pliable and not to become hard and brittle with age.

UNDERGROUND LINES

369. For the purpose of affording better protection against the elements and other disturbing causes, and to do away with unsightly and inconvenient masses of overhead wires, lines generally in the form of cables are often run *underground*. In some instances properly protected cables have been buried directly in the earth, and in other cases they have been given the additional protection afforded by encasing them in concrete, or by enclosing them in wooden boxes filled with pitch, systems of this kind being known as **solid systems.** Present systems, however, are almost all of the type employing some form of **conduit** or **duct** to protect the cable, and arranged so that the cable may be introduced or removed as desired. To make this operation possible, means for getting at the conduit such as **manholes** must be introduced at points spaced from 350 to 400 ft. apart. At each of these manholes, the sections of conduit joining them end, and cables may be drawn in or out of the open ends.

MATERIALS OF CONSTRUCTION

370. **Conduit:** Many types of conduit have been proposed and used, of which the following are examples of the most successful.

371. The **pump log conduit,** Fig. 235, is made out of creosoted wood, and is generally laid without concrete. The sections are about 8 ft. in length with holes varying from 1½ to 3 in. in diameter. The ends are doweled to preserve alignment, and 2 in. creosoted planks are placed on top of the conduit to protect it from picks, etc. This form of conduit is cheap to install, but has a life probably not exceeding twenty-five years under the most

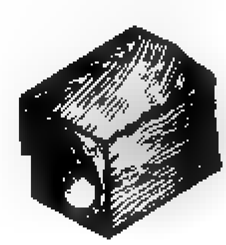


Fig. 235

favorable circumstances, and not more than ten or fifteen years under less favorable conditions.

372. Wrought iron pipe surrounded by *concrete* is successfully used for conduit, having proved one of the best forms. Although the pipe may rust away in time, the concrete becomes sufficiently hard in the interval to afford ample protection for cables. This system however is quite expensive to build. A similar system which is somewhat cheaper, makes use of *thin sheet iron pipes lined with cement,* the pipes being embedded in *concrete.*

Wrought iron pipe conduit is sometimes laid directly in the ground, no concrete being used.

373. A form of conduit in very general use is made of **vitrified clay, terra cotta,** or **earthenware,** enclosed by *concrete.* Various shapes are on the market, among which are the **single duct,** Fig. 236, and the **multiple duct,** Fig. 237.

Fig. 236

Fig. 237

374. One of the latest forms of conduit is made in the form of pipes, Fig. 238, of a material called **bituminized fiber.** Among other advantages it is claimed that this form of conduit is

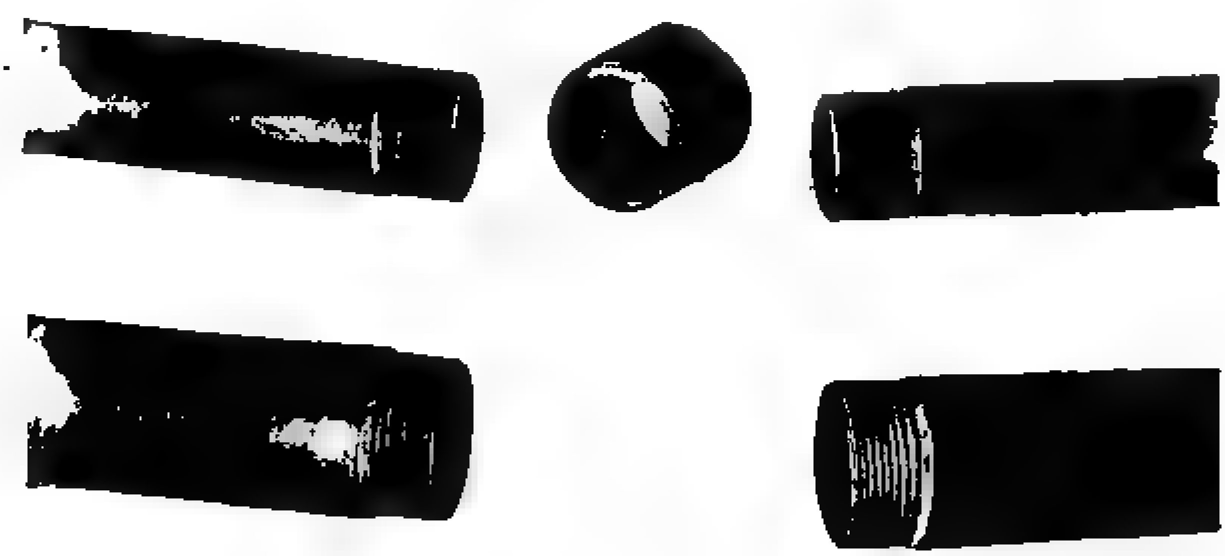


Fig. 238

moisture proof and non-corrosive. It is made in lengths of 2½ to 7 ft., and the ends are provided with joints that may be made water and gas tight. It is sometimes embedded in concrete when laid.

Fig. 239

375. Handholes, Fig. 239, and **manholes,** Fig. 240, also known as **splicing chambers,** are generally built of concrete or brick. They are constructed with iron covers to provide a means of entrance to the conduit and provision is usually made in the case of manholes, to drain away moisture to the sewer.

376. Cable: The cable used for underground work is generally covered with a *lead sheath* to protect it from moisture and chemical action. In addition to this, that intended to be laid directly in the ground is provided with an *armor* of galvanized steel wire or tape, and wrappings of tarred jute.

Fig. 240

377. Connectors: Copper **connectors** or **sleeves** of straight and T form, Fig. 241, may be used in splicing together the wires of cables. They have a cross-sectional area equal to that of the wire they fit, and are usually split along one side, so that they may be forced together into close contact with the

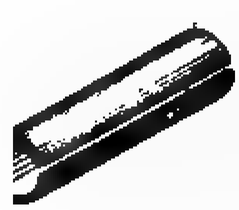


Fig. 241

wire, by means of the pliers or hammer. Connectors of this type are always soldered.

378. Sleeves: Lead sleeves, which are often used to connect the lead sheaths of cables at a joint, are lead tubes with an in-

Fig. 242

ternal diameter somewhat larger than the external diameter of the sheath, the diameter of the sleeve depending on the number of conductors, character of joints, etc. In the case of single conductor cables, an internal diameter $\frac{1}{2}$ in. larger than the external diameter of the sheath is sufficient. In the case of multi-conductor cables, on account of the space required by the joints, and also in the case of high tension cables, on account of the additional thickness of insulation required at the joint, it may be necessary to increase the difference in diameter to 1 or $1\frac{1}{2}$ in. Sleeves should be of such length that each end will overlap the lead sheaths of the cables by at least $\frac{1}{2}$ in., and the lead should be at least as thick as that of the sheaths. Sleeves of this kind are joined to the cable sheaths by wiped joints.

Fig. 242 shows a *lead T* used to connect the lead sheaths of cables, in making one form of branched joint called a *T joint.*

379. Underground Junction and Joint Boxes: The sheaths of cables are generally joined together with a lead sleeve, but where it is desirable to obtain quick and easy access to the conductors, for changing connections, testing, etc., a form of **junction box** is used. Fig. 243 shows one of many types of these devices. This is arranged, so as to be rendered

Fig. 243

moisture proof, by making wiped joints between the box and the cable sheaths and placing a rubber gasket underneath the cover.

380. Fig. 244 shows a **joint protection coupling** for connecting

Fig 244

the armor of steel taped cables. It may also be used for wire armored cables. This device simply connects the armor, the lead sheath being connected by a sleeve in the regular manner.

Fig. 245

381. In Fig. 245-246 are shown **split joint-boxes** for cables armored Special provision armor,

Fig. 246

and the joint-boxes are rendered moisture proof by filling them with insulating compound.

Fig. 247 shows another form of this type of joint-box, which is provided with brass nipples to which the cable sheaths may be

soldered. The armor is secured by split couplings, which are corrugated at one end where they clamp the armor, and provided

Fig. 247

with grooves at the other end which clamp around suitable projections on the nipples. This box may also be used as a junction box.

382. **Terminals:** These are devices which are placed at the ends of cables the wires of which are insulated with materials liable to be affected by moisture. They afford a convenient method of making connections, and prevent moisture from entering the ends of the cable. Terminals are made in many different forms for different classes of service. In general they consist of some form of cup, generally made of metal, which

Fig. 248

Fig. 249

is connected to the cable sheath. The conductors of the cable are connected to rubber covered leading out wires inside this cup. After the joints have been made and insulated, the cup is filled with an insulating compound, and the open end protected by a cap of insulating material. Fig. 248 shows a terminal for *open air* work and Fig. 249 a similar terminal for *indoor* work.

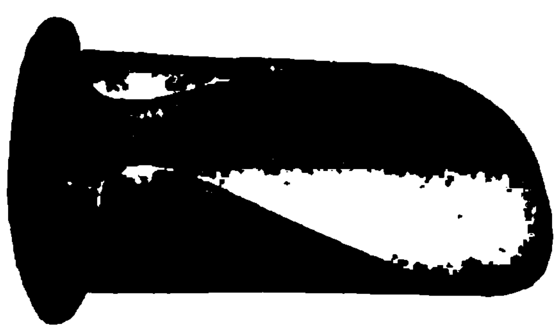


Fig. 250

383. Duct mouth protectors, Fig. 250, are used to prevent the edges of the ducts from injuring the lead sheaths of cables. That shown in the illustration is made of zinc or galvanized iron.

CONSTRUCTION TOOLS

384. A few tools used specially for the installation of underground cable lines are as follows:

Rods of wood, Fig. 251, about one inch in diameter by 3 or 4 ft. long, provided with coupling devices at the ends by which they may be joined together, are used to pull the draw-rope through the conduit. This operation is called *rodding*.

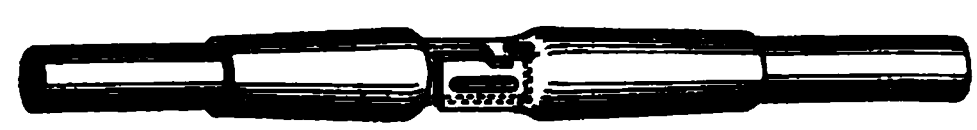


Fig. 251

385. In place of rods a tempered steel tape, about $\frac{3}{16}$ in. by No. 19 B. & S. G., may be pushed through the duct and used to pull in the draw-rope. This device is known as **a fish tape** or **snake.**

386. In some cases, particularly when several ducts are to be rodded at one time, instead of pulling in draw-ropes, wires are drawn in, No. 10 or 12 B. W. G. iron wire usually being employed. These are left in the ducts and can be used later to draw in the rope. Such wires are known as **fish wires.**

387. The **draw-rope** is generally a manilla rope of the best quality, varying from $\frac{3}{4}$ to $1\frac{1}{2}$ in. in diameter. The ends may be provided with thimbles, to which are fastened short lengths of chain, provided with swivels at the ends and suitable hooks to

fasten to the cable grip.

388. When a *capstan* or *winch,* located on the street, is used to furnish the power for pulling the cable, an arrangement of pulleys, similar to that shown in Fig. 252, is used to lead the draw-rope out of the manhole. A special winch, Fig. 253, arranged to work in the manhole is sometimes used.

Fig. 252

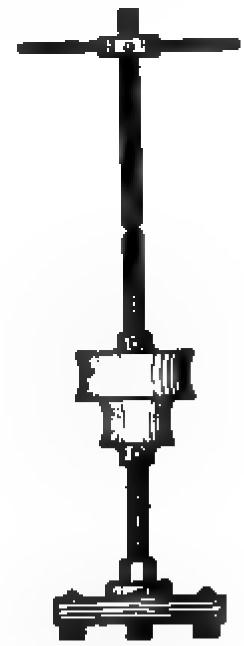


Fig. 253

389. The **chipping knife,** shown in Fig. 254 has a heavy blade with a strong edge and broad back, and is used for cutting lead sheaths. In use it is held and guided with one hand, while it is forced into the lead by striking it on the back with a hammer.

Fig. 254

390. The **shave hook,** Fig. 255, has a blade with a sharp edge and is used to scrape the surfaces of lead sheaths and sleeves, where a joint is to be made.

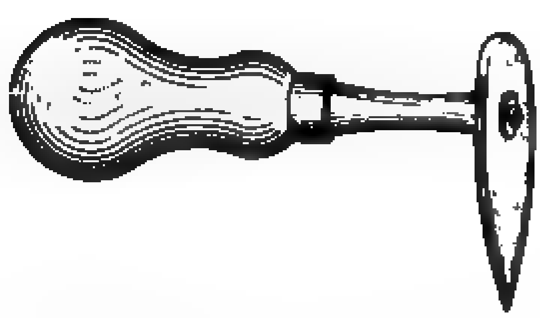


Fig. 255

391. Wiping cloths or **pads** are made of several thicknesses of the kind of cloth known as *ticking,* and are rectangular in shape measuring about 3½ by 4 in. One surface is coated with tallow, or chalk and tallow, to prevent the solder from sticking to it.

INSTALLATION

392. It is not considered necessary to treat further of the methods of building duct lines, manholes, etc., as this part of the work is almost invariably done by contractors having much experience in this line of construction.

393. **Preparing the Ducts:** Preparatory to drawing in the cable, the ducts should be cleaned, either by forcing water through them at a high velocity, or where sufficient pressure is not available, by drawing a mandril through them. This is made of a round piece of wood about 3 ft. long and is provided with a scraper of leather or rubber to drag out any foreign matter that may have lodged in the duct.

394. Before anything can be drawn through a duct, however, it is necessary to get a rope through it, which is generally done by *rodding.* A bundle of rods are placed in a manhole, and the workman pushes one rod into the duct, then attaches another section and pushes that in, continuing until the first section reaches the next man hole. The draw-rope is then fastened to this section, and the rods drawn back and disconnected, thus pulling the rope through the duct. As mentioned before, *fish wires* may be employed in place of rope, when several ducts are rodded at one time.

395. Obstructions, such as pieces of cement, may generally be removed, by mounting some such device as a piece of steel pipe on the end of the first rod, and drilling the cement away or knocking it loose. If the obstacle cannot be removed otherwise, it may be necessary to measure the distance to it with the rods, and open the conduit at this point.

396. **Drawing in Cables:** After having made sure that the ducts are in proper condition, the *reel* carrying the cable is conveyed to the first manhole, and mounted over it on *wheels* or *reel jacks,* so that it can be turned. The reel is placed on that side of the manhole at which the cable is to enter the duct, and arranged so that the cable comes off from the top in unwinding. As in the case of aerial cables, the lagging, screws, and nails are carefully removed.

397. A *protector* is now placed in the mouth of the duct to prevent injury to the cable sheath, the cable grip adjusted, and the draw-rope attached. The other end of the draw-rope is then fastened to a *capstan* or *winch*, and the cable pulled into position. The speed at which the cable may be drawn varies from 5 to 30 ft. per minute, according to conditions. Care should be taken not to bend cables too sharply where they are fed into ducts, and to prevent the sheath from being cut on the edge of the duct or manhole. The ends should also be kept carefully sealed to prevent the entrance of moisture. In case the cable or any conductor in it is provided with identifying marks, all sections must be laid in the same direction to insure proper registration. A sufficient length of cable should be left in each manhole, to enable the cable to pass around the walls where it should be suitably supported.

398. *Protectors* or *cushions* of lead, rubber, or other suitable material should always be placed under the cables at the mouths of the ducts.

399. Splicing: Lead covered cables, the wires of which are insulated with rubber, are spliced as follows:

400. The cable is first examined carefully from the edge of the duct to the sealed end, in order to discover any injury to the sheath. Then, after seeing that protectors have been placed in the mouths of the ducts, the cables are bent around the sides of the manhole and supported on suitable brackets, the ends being brought into position for splicing, and allowed to overlap sufficiently to permit the proper distribution of the joints in multiconductor cables. The splice when finished should come between supporting brackets, so that there will be no strain upon it.

401. Following this the lead sheaths are marked at the points to which the lead is to be removed to expose the conductors for the purpose of splicing. The amount of lead to be removed is governed entirely by the character and size of the cable. Grooves are then cut around the sheaths at these points, generally with a chipping knife and hammer. In order to prevent the edge of the knife from damaging the insulation, care should be taken not to cut entirely through the sheaths.

402. After the grooves are made the sheaths are cut lengthwise from the grooves to the ends. In order to avoid injuring the insulation, this is done with the knife held at such an angle, that the edge will pass between the lead and the insulation without cutting the latter. After this cut is made, the loosened portions of the sheaths are removed with the pliers and all sharp projections and edges carefully smoothed.

403. Multi-conductor cables have a belt of insulation placed around the bunch of insulated conductors, the lead sheath being placed over this. A portion of this outer insulation is removed, allowing a suitable length to project beyond the sheath. In doing this care should be taken to avoid injuring the insulation of the conductors.

404. A suitable *lead sleeve* (Art. 378) is next prepared, by scraping the outer surfaces at the ends with a *shave hook* or *knife*, for a length of about 2 in., the cleaned portions being covered with a *flux* such as tallow. This sleeve is then slipped over the more convenient end and pushed back out of the way.

405. The cable ends being in the proper position, the individual wires are straightened out and spliced together one at a time, the others being carefully bent back out of the way. An approved method of splicing is as follows:

406. The insulation is removed from the end of each wire for

Fig. 256

a suitable distance, the conductor cleaned and tinned, Fig. 256, using rosin or tallow for a flux, and the ends soldered together,

Fig. 257. The splice is made with the aid of a *copper connector*, Fig. 241, or any other suitable method* is used. After soldering

Fig. 257

all surplus solder is carefully removed, so that no sharp projections or edges are left on the joint.

407. Following this the joint is thoroughly insulated by applying spiral wrappings of pure rubber tape, Fig. 258, to a thickness of from $\frac{1}{64}$ to $\frac{1}{32}$ in. This is covered by rubber compound

Fig. 258

tape, applied spirally, until a total thickness slightly greater than that of the original insulation is secured. A layer of friction tape is then applied over all the conductors.

408. While the preceding method is reliable for low and medium potentials, for high potentials, such as 2,200 volts and more, it is advisable to cover the joints with rubber, which is vulcanized after it is in place. The following method is recom-

*The Western Union type of joint may be used for solid wires, while stranded wires may be woven together, or a type of wrapped joint used.

mended.

409. After the copper wire or strand has been spliced, it is wrapped with a high grade of vulcanizable rubber compound. In wrapping the splice it is of the utmost importance that all materials used, as well as the ends of the conductor, are scrupulously clean. It is also very important that the operator's hands should be entirely free from moisture of any kind. After the rubber has been applied to the proper thickness, which usually makes the diameter somewhat larger than the outside diameter of the insulated conductor, the splice is wrapped with a fine grade of cotton cloth. Vulcanization is then effected either by boiling the splice in a small tank containing vulcanizable wax, or, in some cases, in a portable vulcanizing press. If the latter is used the cotton wrapping is not necessary. The joint is then finished with friction tape.

410. After the insulation has been applied the lead sleeve is drawn over the joint, each of the ends being allowed to extend equally over the cable sheaths, and the ends of the sleeve worked

Fig. 259

down with a mallet, so that they fit the cable sheaths closely, Fig. 259, care being taken to keep the sleeve concentric with the sheaths. Then the sleeve and sheaths are joined by means of *wiped solder joints*,* Fig. 260, which must be made so as to be moisture proof, and finally the completed joint, Fig. 261, is placed in position.

*See Art. 415.

411. T splices are made in much the same manner as straight splices. The wires are joined in this case by a *split T copper*

Fig. 260

connector, Fig. 241, or other suitable type of joint, and a special *lead T*, Fig. 242, *open* along one side is used to connect the

Fig. 261

sheaths. This T is slipped over the branch cable and, when the joints have been made and insulated, is brought into position, the split side closed around the main cable, and the edges caused to register neatly. They are then soldered, and the ends of the T connected to the sheaths with wiped joints.

412. A better joint for leading off a branch is of the Y form. The main cables are arranged for splicing in the regular way, and the branch cable placed parallel to the main cable, to which it is to be spliced, the lead sheaths being separated about $\frac{3}{4}$ in. by a block of wood. After each connection is made between the wires of the main cables in the regular manner, the corresponding wire of the branch cable is placed alongside the joint, and securely fastened to it by a serving of fine copper wire. Then all three wires are soldered firmly together and insulation applied as in the case of a straight joint. Following this the lead sleeve is placed in position, and worked between the sheaths of the main

and branch cables. Finally wiped joints are made at the ends of the sleeve. Fig. 262 shows a joint of this kind.

Fig. 262

413. Cables insulated with material that tends to absorb moisture, such as paper, require special precautions in the operation of splicing, to remove any moisture that may be present, and also to prevent the entrance of moisture after the joint is completed. Before splicing, the ends should be tested, after they are opened, by dipping them into hot insulating compound, the presence of moisture being denoted by bubbles. If bubbles appear the cable should be cut back a little at a time, until there is no further indication of moisture. If no more can be cut off and moisture is still present, heat should be applied to the lead sheath, beginning at the duct mouth and slowly passing to the end of the cable, the object being to expel the moisture from the open end. If allowable, a gasoline furnace or torch may be used for this purpose; otherwise the heating may be accomplished by pouring very hot insulating compound over the cable, and catching it in a vessel held underneath.

414. Joints in such cables are generally insulated by spiral wrappings of tape, of the same material as the original insulation, applied to a thickness somewhat greater than that of the original insulation. After the tape has been applied to all the conductors, the splices are boiled out by pouring hot insulating compound over them, until no bubbles appear to denote moisture.

When the joints in the separate conductors have been insulated and boiled out, a wrapping of suitable tape is applied over all the conductors, the splice boiled out again, and the lead sleeve soldered in position.

The joint is now completed by filling it with hot insulating compound poured through a hole cut in the sleeve, after which the hole is covered with a thin lead cap, carefully soldered in place.

415. *Wiped Solder Joints.* The following is a general description of the method of making wiped joints. After the lead sleeve is in place and the ends have been worked down to the cable sheaths on each side, the sheath is scraped bright for a distance of about 2 in. from one end of the sleeve, and the sleeve also scraped for the same distance in the other direction, if this has not been done before. Strips of paper about 2½ in. wide are then pasted around the sheath and the sleeve, about 1½ in. each side of the joint, and the brightened lead between them coated with tallow candle grease. The joint at one end of the sleeve is prepared in this way, the other joint being left until the first is finished. The joint should be firmly supported in such a position that there is at least 4 in. space below and on both sides of it.

Previous to this the solder should have been melted, ordinary *half and half* generally being used, and heated to a temperature just sufficient to char but not ignite a soft wood chip. The solder being ready, the *wiping cloth* or *pad*, previously warmed until it is pliable, is held in the *left* hand so as to form a sort of trough. The dross is then removed from the molten solder and a quantity taken in a warm ladle and poured slowly over the joint. The stream should be distributed so as to heat all parts of the joint as uniformly as possible, in order to avoid melting a hole in the lead. The wiping pad, which is placed below the joint, catches the solder as it runs off, and this being held in contact with the under side of the joint, warms that also.

As the joint becomes warm enough the solder caught in the pad is worked around onto the top, and more solder poured onto this, caught in the pad so as to heat the under side, and also worked around. This process is continued until the solder on the joint becomes plastic. Then if the lead has become thoroughly tinned, and is hot enough to keep the solder plastic during the balance of the work, the pouring is discontinued.

The surplus solder is now wiped off with the pad, and the rest worked around the joint, from bottom to top, to form a sort of bulb extending between the edges of the paper strips. Finally the joint is finished by lightly drawing the pad across the top, and removing any portions of solder that project beyond the edges of the paper strips. The joint may be caused to set rapidly by fanning it, or spraying a little water upon it. A small looking

glass is serviceable to see if the bottom of the joint is properly made, and the joint should be carefully inspected to insure smoothness, solidity, and the absence of air holes.

416. *Splicing Armor.* When lead covered cables are armored with steel wire, the wire must be spliced in addition to making the regular joint. Previous to making the regular joint, the armor wires should be bound with tie wires at each side of the joint, and bent back out of the way. When the joint is completed, it is protected by wrappings of jute placed over the lead sleeve. Then the armor wires from one side are bent down and spaced uniformly around the sleeve. As the sleeve is larger than the cable sheath, spaces are left between the wires. These are filled with the armor wire from the other side, the wires being interlaced. Any surplus wires are cut off and butted against the corresponding wires on the other side. By this method the joint is covered completely and evenly with armor wires. A tight serving of wire is then wound around the armor wires, over the entire length of the joint, and carefully soldered to the armor.

417. Cables armored with steel tape are treated in a somewhat different way, the armor being connected by a *protection coupling*, Fig. 244.

418. When a *split joint box*, Figs. 245-246, is used, the armor is prevented from springing loose during the process of making the joint, by servings of copper wire, placed to come just between the corrugated clamps and the body of the box. The armor at each side is removed back to the binding wires, by filing it through with a sharp three cornered file just inside of the wires, and then unwinding and breaking it off. The jute wrapping between the armor and sheath is also removed to the same point.

The joint is now made in the regular manner except that the lead sleeve is omitted, care being taken in cutting away the lead sheaths, that enough is left so that they project at least 2 in. inside the box. Packings of some material, such as rubber hose, are then placed around the lead sheaths where they pass into the box, and tape applied if necessary, so that when the box is put together the packings will be clamped snugly. Finally the grooves around the rim of the box are filled with jute saturated

with hot insulating compound, the halves of the box bolted together, and the box itself filled with hot insulating compound. In clamping the armor care must be taken not to put any severe bending strain upon the cable, and it may be necessary to fill up any space remaining between the armor and clamp with thin sheet metal liners.

419. As the type of box, Fig. 247, is generally moisture proof without a compound filling, it may be used as a junction box. For this purpose insulated terminal posts may be mounted in it, so that connections may be changed readily.

420. Connections to Underground Lines: One method of connecting an underground line to an overhead line is to place a pole near a manhole or handhole, and lead an iron pipe, or other suitable form of conduit, of sufficient size to receive the cable, from the manhole or handhole far enough up the side of the pole to protect the cable from injury (Fig. 239). The conduit is laid in a long even curve so that there may be no difficulty in drawing the cable through it. The cable is ended in a junction box and, if the line is to be continued by open line wires, the wires leading from the cable are connected to them by rubber covered spider wires. Lightning arresters may be inserted between the cable and the aerial line to protect the cable from high potential currents.

421. A method of connecting signal apparatus to underground cables, is to run iron pipe conduits from a manhole above the surface of the ground, and mount a junction box on the conduits at a convenient height. The cables are brought up to the box through the conduits and the desired connections made.

422. Electrolysis: In connection with underground cable lines, this term is understood to refer to the *pitting* or *eating away* of *cable sheaths*, due to the electrolytic action set up by stray currents, generally from the ground return circuit ot an electric railway. Thus if the cable is a better conductor than the ground or rails, the current flows to and along it, until another path of lower resistance offers itself, at which point it leaves the cable.

423. Danger from electrolysis occurs at points where the current leaves the cable, or where it is electropositive to the

earth and surrounding conductors. Thus if current can be prevented from flowing to the earth from the cable, electrolysis will not occur. Although conduits of insulating material tend to decrease electrolysis, they cannot be depended upon to entirely prevent it.

424. Points where the cable is electropositive to surrounding conductors may generally be determined by means of a milli-voltmeter, attached to a pair of testing rods. These are metal rods armed with points sharp enough to make good contact with the cable sheath and other conductors, but not sharp enough to injure the sheath. The method of making the test is to place the point of one of the rods on the cable sheath, and the point of the other rod on surrounding conductors. Then, by observing the direction in which the needle of the milli-voltmeter is deflected, the direction of the current can be ascertained, and therefore whether the cable is electropositive or not at this location.

425. Various methods are used to prevent electrolysis. For example, the trolley wire or third rail should be connected to the positive side of the generator. The track should be well bonded, and the bonds maintained in good condition, so that the resistance of the track return circuit may be as low as possible. In addition, low resistance track return feeders, connected to the track at intervals, tend to prevent the current from seeking other return circuits. Danger points, where cable sheaths are electropositive to surrounding conductors, may be bonded to the track return circuit, or low resistance return feeders may be run directly from the generator to such points, so that the current will flow from the cable by a metallic path instead of to the earth.

426. Testing: Before connections are made to cables, the conductors should be tested for *broken wires*, *crosses*, and *grounds**. This may be done either before the cable is unreeled or after it is installed.

427. *Broken Wires.* To make this test all the wires at one end of the cable should be temporarily joined together and grounded to the lead sheath. To the other end of the sheath

*This refers to wires grounded on the lead sheath.

one terminal of a battery is connected, the other terminal being connected to a voltmeter, bell, or telephone receiver. The wire leading from the voltmeter or other instrument is now connected in turn to each of the wires of the cable at this end of the sheath. If the voltmeter needle is permanently deflected, the bell rung, or a continuous clicking heard in the telephone receiver, the connection in this case being made by rapidly tapping the ends of the wires, it indicates that the wire is continuous. Defective wires should be marked at both ends of the cable.

428. Due to the capacity of a long wire, particularly in a cable, the voltmeter needle will probably show a deflection when contact is made, even if the wire is broken. Therefore a long enough interval must be allowed to elapse, to allow the wire to become charged, when the needle will return to zero in case the wire is broken. For the same reason, at the first one or two contacts a click may be heard in the telephone receiver, but only a continuous clicking at every contact denotes a continuous and unbroken wire.

249. Magneto testing instruments cannot be relied on when testing wires having considerable capacity, since sufficient current may flow, even when the circuit is not continuous, to ring the bell and thus indicate a continuous circuit.

430. *Crosses and Grounds.* One end of the cable should first be examined to see that all the wires are separated from each other, and from the sheath, so that there are no crosses or grounds at this point. All the wires at the other end are then connected temporarily together and to the sheath, and one terminal of a battery connected to them, the other terminal being connected to a voltmeter or other instrument as just described. The cable wires are now disconnected one at a time, and connected to the wire from the instrument. A permanent deflection of the voltmeter needle, ringing of the bell, or continuous clicking in the telephone receiver, indicates a cross or ground. If the indication shows that the wire is crossed or grounded, the defective wire should be marked and connected back with those still untested. The test should be continued until nothing remains but defective wires. The corresponding ends of the defective wires at the other end of the cable should now be found and marked.

431. If cables are subjected to high voltage tests, it is essential that the voltage be raised gradually at the beginning of the test, and lowered gradually at its end, so as to prevent impulsive rises of voltage. One method of accomplishing this is to insert a resistance in the circuit, composed of a metal tank containing water, into which a sheet iron plate may be lowered without touching the tank. One side of the circuit is connected to the tank and the other to the plate.

MAINTENANCE

432. At the end of regular intervals of say three months a careful inspection should be made of the cable line. This should include manholes, covers, cables, duct mouth protectors, terminals, junction boxes, etc., and the condition of the conduit so far as that can be ascertained. The cables should also be tested as often as necessary, to determine if any changes should be made in the means taken to prevent electrolysis. Small defects when noticed should be repaired at once.

433. In entering and leaving manholes, care should be taken not to step on the cables. In making additions, repairs, or alterations, the cables should be moved as little as possible, and in case they are moved, care should be exercised to prevent straining the joints. In cold weather cables should be warmed before attempting to bend them, and in any case sharp bends should be avoided.

434. The notes in *Aerial Cable Lines* (Art. 365) with regard to insulation resistance tests, and the Varley and Murray Loop Tests, also apply to underground cables.

435. If the conductors of underground cables are accessible, the tests mentioned in Art. 364, may be employed.

436. *Electrostatic Capacity Tests for the Location of Breaks.* In case a wire in a cable breaks, the ends may be entirely insulated from the other wires and the sheath. Under these conditions the resistance of the wire is equal to the insulation resistance between its portions, since the only current that can pass between the portions, must leak through or across the insulation.

If the previous capacity of the wire is known the location of the fault may be determined, by measuring the capacity of the broken wire from the testing station to the point of rupture and comparing the value with the original capacity, the distance from the testing station to the point of rupture having the same proportion to the total length of the wire, that the capacity measured has to the original capacity. If the cable is one having considerable capacity per unit length, so that slight changes in length give rise to relatively large variations in capacity, this method is fairly accurate.

437. The capacity of the wire may be measured by comparison with the capacity of a standard condenser, connections being made as shown in Fig. 263.

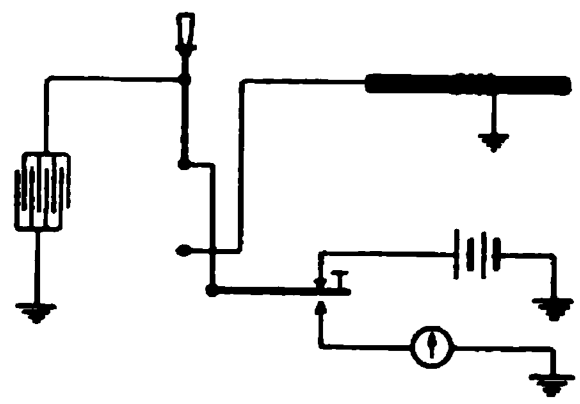


Fig. 263

It will be noted that the apparatus is arranged, so that either the condenser or the wire may be charged from the same battery, and discharged through the galvanometer. Under these circumstances, the relative capacities are proportional to the deflections produced on the scale of the instrument, provided it is a *Ballistic galvanometer**. If the galvanometer is shunted, the readings must of course be multiplied by the proper factor**.

438. If an ordinary galvanometer is used, or one in which the motion of the needle is damped, a correction must be made as follows:

The first swing of the needle is observed and the deflection d' noted. The second swing in the same direction is also observed, and the deflection d'' noted. Then the true deflection d on the scale is obtained from the equation,

$$d=d'+\frac{d'-d''}{4}$$

If the deflections given by the discharge of the standard condenser and the wire are practically equal, this correction is not required, as it would be the same in each case.

*A *Ballistic galvanometer* differs from the ordinary galvanometer, in that it is constructed to have little or no damping, and is provided with a comparatively heavy needle, which has a relatively long period of oscillation.

**See Magnetism and Electricity.

439. Suppose that the standard condenser, with a capacity of C_s, when charged from the battery for a certain length of time, say one minute, gave a deflection d on discharge through the galvanometer. Also that the wire, with an unknown capacity C_x, when charged from the battery for the same length of time, gave a deflection d_1, on discharge through the galvanometer.

$$\text{Then } C_s : C_x :: d : d_1,$$

$$\text{and } C_x = C_s \frac{d_1}{d}.$$

440. If a good wire of the same length as the broken wire and a capacity equal to the original capacity of the broken wire is available, a simple method of finding the location of the break is as follows:

The faulty wire is first charged and the deflection of the galvanometer noted when it is discharged through it. Second, the good wire is charged and the deflection noted on discharge through the galvanometer. Then the distance from the testing station to the break is to the length of the good wire as the first deflection is to the second deflection.

441. The location of breaks by capacity tests is generally not reliable, if the insulation resistance between the ends of the broken wire is less than one megohm. Therefore the insulation resistance between these parts should be measured before applying the capacity test.

SUBMARINE LINES

442. Rubber insulated cables with an extra heavy lead sheath have been satisfactorily used for submarine lines where the bottom is soft, and there is no danger from mechanical injury such as from anchors. In some cases the lead sheath is covered with one or two layers of braid saturated with a waterproof compound. Where danger of mechanical injury exists, cables must have the additional protection furnished by a bedding of tarred jute, over which is placed *steel tape* or *wire armor,* followed by a

heavy covering of tarred jute. Wire armor should be used if the cable is liable to be subjected to much tensile strain. For long distance submarine telegraph work lead sheaths are often omitted, as sufficient protection can be obtained by several layers of insulating material. Gutta-percha is excellent for this work as water has practically no effect upon it. Such cables are always armored however.

INSTALLATION

443. For short distance work, such as crossing rivers and small lakes, the cable carrying the reel may be mounted at the bow of a tug or flat boat, the reel being supported on a heavy shaft so that it can revolve freely. The cable is passed to the stern of the boat over rollers or pulleys and the shore end fastened securely at the proper location. The boat is then propelled slowly across the water to the point where the cable is to land. Care must be taken to brake the reel so that the cable will not over-run and to prevent any damage to the cable in passing it along the boat. When the landing is reached the boat should anchor or beach prow on, after which the remainder of the cable is unreeled and dropped alongside, the end being carried ashore.

444. When the water is shallow, as at the landings, the cable should be laid in trenches, or submarine ditches, to protect it against ice and the keels of boats. The landings should be plainly marked with a sign, "CABLE LANDING, DO NOT ANCHOR," to prevent boats from anchoring near the cable.

445. Construction at Draw-bridges: An important use of submarine cable is at draw-bridges, where aerial lines cannot be employed on account of the height of passing vessels. The cable is laid along the bottom from bank to bank, or a trench may be provided, if the cable is liable to injury from passing vessels as explained before. At the landings the cable may pass into manholes, also known as *submarine terminals*, if it is to be spliced to underground cables. Otherwise it may be terminated in junction boxes, where connection is made to aerial cables or open wires. In the latter instance lightning arresters may be placed in the junction boxes to prevent lightning discharges

from entering the cable. The cable should be securely fastened at the ends so that the connections are not subjected to strain.

446. In some cases it is necessary to connect the cable to the draw span. One method of doing this is to run the cable from the banks to the end of the protection or fender pier. Here it is brought up from the water and continued to the center of the draw span as an aerial cable. For this purpose a cable pole is erected at the end of the protection pier, of sufficient height so that a messenger may be run from the top of it to the center of the draw span, the cable being carried up this pole and along the messenger. The cable is protected by pipe or other suitable means from the surface of the water to the top of the protection pier. To allow the draw span to turn without twisting the cable, a device called a *turntable* is erected at the center, for the purpose of supporting the cable at this point. It is mounted on bearings in such a way that it remains stationary when the bridge turns.

MAINTENANCE

447. In case it is necessary to repair a short cable, or to examine it for injury, one end may be securely fastened and the other disconnected and drawn out upon the bank, until the entire length of the cable is raised above the water, or such portion as is desired. The cable may then be examined or repaired, that portion over the water being reached by the aid of a boat.

In case navigation does not permit this method, the cable may be caught with a grapnel and brought up to a boat, or a temporary cable may be laid and the damaged cable pulled out for repairs.

448. The tests for locating faults that have already been described apply to submarine cables as well.

In case of breaks or damage to lead covered cables, repairs may be made as previously described in connection with splicing lead covered cables. On non-leaded cables with rubber insulation, it is necessary to thoroughly vulcanize the rubber tapes so as to cure the rubber and render it homogeneous, elastic, and water-tight. It is recommended that this part of the work be done by experts.

EXAMINATION QUESTIONS

(1) What are messenger wires?

(2) Name two methods by which cables may be attached to their messenger wires.

(3) Which should have more sag when it is strung, a messenger wire installed in cold weather or one installed in hot weather?

(4) When a cable containing several conductors is spliced, why are the joints in the conductors staggered?

(5) What is a hand made cable?

(6) Name one advantage of placing junction boxes at frequent intervals along an aerial cable line.

(7) What is a convenient method of connecting a voltmeter to conductors without removing the insulation?

(8) Are underground cables ordinarily buried directly in the earth or run through ducts?

(9) By what means is access had to the ducts for the purpose of installing or repairing cables?

(10) What are duct mouth protectors used for?

(11) What method is generally used to get the draw-rope through the ducts?

(12) Why is a lead sleeve placed over a splice in a lead covered cable?

(13) If current flows from the earth to a cable sheath at A and flows from the sheath to the earth at B, at which point is there danger from electrolysis?

(14) In testing a long wire which is known to be broken the voltmeter needle shows a deflection when contact is made but quickly returns to zero. What causes this?

(15) Is the location of breaks by capacity tests reliable if the resistance between the ends of the broken wires is low?

(16) How is a submarine cable generally protected from mechanical injury?

D. C. RELAYS

1. The **relays** used in signal work are a development of the *telegraph relay* described in *Magnetism and Electricity,* additional contacts generally being provided and so arranged that some will be closed and others open when the armature is attracted.

2. Relays are constructed in several different forms, to meet the various requirements of signal work. The distinguishing features of each form are briefly as follows:

3. Neutral Relays: A relay the armature of which operates regardless of the direction in which the current flows through the coils, is known as a **neutral relay.**

4. A relay having *two* sets of coils, and *two* armatures arranged to interlock with one another mechanically, is known as an **interlocking relay.**

5. A relay the armature of which takes an appreciable time to release, is known as a **slow releasing relay.***

6. A relay which is composed of *two* magnets or sets of coils acting in *opposition* to each other is known as a **differential relay.**

7. A relay the coils of which are double-wound, that is, having *two* separate windings *insulated* from one another, is known as a **compound wound relay.****

8. A relay consisting of a *solenoid*† composed of insulated

*Also known as *slow acting* relays.
**Also known as *double-wound* relays.
†See **Magnetism and Electricity,**—*Electromagnetism.*

wire, and provided with a *movable core* upon which contacts are mounted, is known as a **solenoid relay.**

9. Polarized Relays: A relay having an armature the position of which is governed by the direction of the current flowing through the coils, is known as a **polarized relay.** This relay is similar to the *neutral type,* generally being equipped with a neutral armature.

The operation of one type of *differential relay* is dependent upon the direction of current through its coils.

NEUTRAL RELAYS

10. In Fig. 1 is illustrated a *two-point* **neutral relay,*** and in Fig. 2, a section taken through the center between the coils, and an inverted view, with the glass ring 1, and tray 2, omitted, showing the armature and contact arrangement.

Relays are constructed with as many as six front and four back contacts.

11. In order to protect the operating parts of the relay from dust, moisture and mechanical injury and also to enable their operation to be readily observed, they are placed in a transparent case. This case consists of a *glass ring* 1, supported by a *brass tray* 2 and supporting a *brass base* 3, these parts being held together with two screws 5. *Rubber gaskets* 4, placed above and below the glass ring, are employed to seal the case thus excluding dust and moisture.

12. The *coils* 6, which extend through the base, are held in position by the two *supporting rods* 7, which are firmly screwed into the base, the *back strap* or *yoke* 8, being screwed to these rods. The coils are *core wound,*** and are covered with a hard rubber casing, to protect them and improve their appearance.

*A relay having *two front* contacts is called a *two* point relay; *three front* contacts a *three* point relay, etc. The back contacts are not considered in this designation.

See **Magnetism and Electricity,—*Electromagnetism.*

13. Bone, brass, or phosphor bronze *armature stops** 9, are placed in the end of the *pole pieces* 10. In addition to overcoming residual magnetism, these stops prevent the armature 11, from sticking, if grease or other foreign substance accumulates on the armature or pole pieces.

14. As shown in Fig. 1, the terminals of the coils are connected to the binding posts which are secured to the yoke; consequently these are the posts to which the wires of the operating circuit must be attached. As the yoke is made of iron these binding posts are of course, insulated from it, this being accomplished in the same manner as that illustrated in Fig. 2, by post 12, which shows the method of insulating the posts from the base. *Insulating paper or linen* 13, is wrapped around the post and lava** or other suitable *insulating bushings* 14, are placed as shown. The wire splice connecting the coils is supported and protected by a *phosphor bronze carrier* 15, which is insulated from the wire by a tube of insulating paper 16.

15. The *contact fingers* 17, which form paths for the circuits controlled by the relay, are rigidly connected to the armature, consequently moving with it. These contact fingers are insulated from the armature in practically the same manner as the binding posts are insulated from the base. The body of the contact finger is made of stiff brass, being attached at its pivoted end to the binding post, by a thin strip of rolled annealed copper† 18, which is very flexible and does not interfere with the operation of the armature. To the free end of the contact fingers are soldered and riveted two pieces of flexible German silver 19, to which are soldered and riveted *platinum contact points* 20—21, the latter being known as the *front contact point* and the former, the *back contact point.*

The front contact points, instead of having but one contacting surface, are generally cut into three parts as shown. This is so arranged in order that a better contact may be assured in case the entire point does not make a good connection, for instance,

*See **Magnetism and Electricity,**—*Electromagnetism.*
**Also called *lavite.*
†Also called *copper ribbon.*

Fig. 1

SECTION A-B

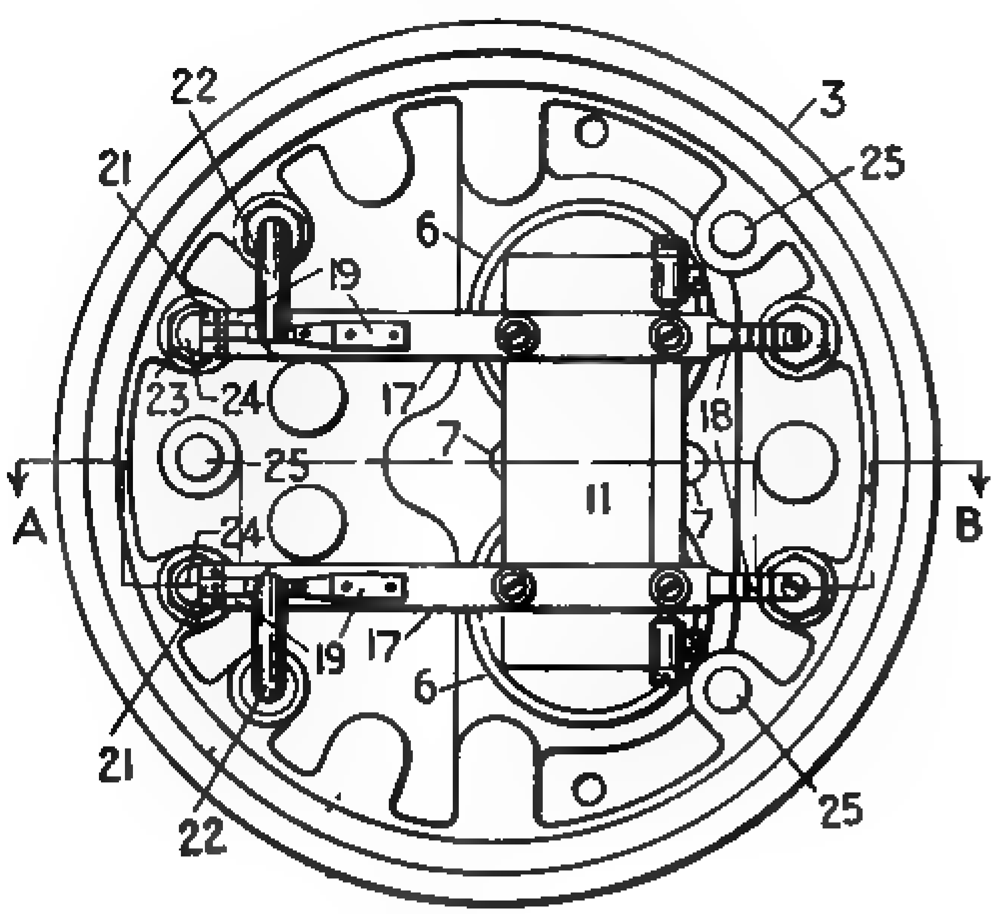


Fig. 2

in case of an uneven surface, or on account of the finger becoming twisted.

16. With the armature in the position shown, the back contact point 20, makes connection with *back contact post* 22. To insure good electrical contact, a *platinum disc* is soldered onto the end of the back contact post. In order to allow the weight of the armature and contact fingers to rest upon the back contact points, and to maintain a proper distance between the pole pieces and armature, the free ends of the brass body of the contact fingers are bent in the manner shown, so that when the armature drops, this bent portion will rest upon the top of the back contact point. As the back contact posts 22, are adjustable (that is, they may be raised or lowered), the air-gap between the pole pieces and armature may be altered as desired.

When the armature is raised the front contact point 21 will make electrical connection with *front contact post* 23, the latter being provided with a graphite or carbon block 24, which forms the contacting surface.

The platinum to platinum contact which is used with the back contact points ordinarily makes a better electrical connection than platinum to graphite or carbon, and was formerly employed for both front and back contacts. However, the use of platinum to platinum for front contacts is being done away with on account of the tendency which there is to fuse the points together when subjected to excessive current, as frequently occurs during lightning disturbances.

As little danger ordinarily results from the fusing of back contacts, the use of platinum is considered satisfactory.

17. The graphite or carbon block when arranged as shown in Fig. 2, is soldered into the front contact post. Trouble is sometimes experienced with this method of construction on account of resistance resulting from the presence of salts caused by corrosion, at the surface of the graphite or carbon blocks. This corrosion is due to the soldering flux not being entirely removed when the soldering is completed.

To overcome this, contact posts constructed as shown in Fig. 3, are frequently employed. The construction shown in sketch A, is used with the relay illustrated in Fig. 1, and that shown in sketch B, with the relay illustrated in Fig. 9. In sketch A, the graphite block C, is held in position by a brass ferrule D, which is screwed onto the post, being held in position by a phosphor bronze pin E. In sketch B, the graphite block F is clamped into the holder G, by means of a screw H.

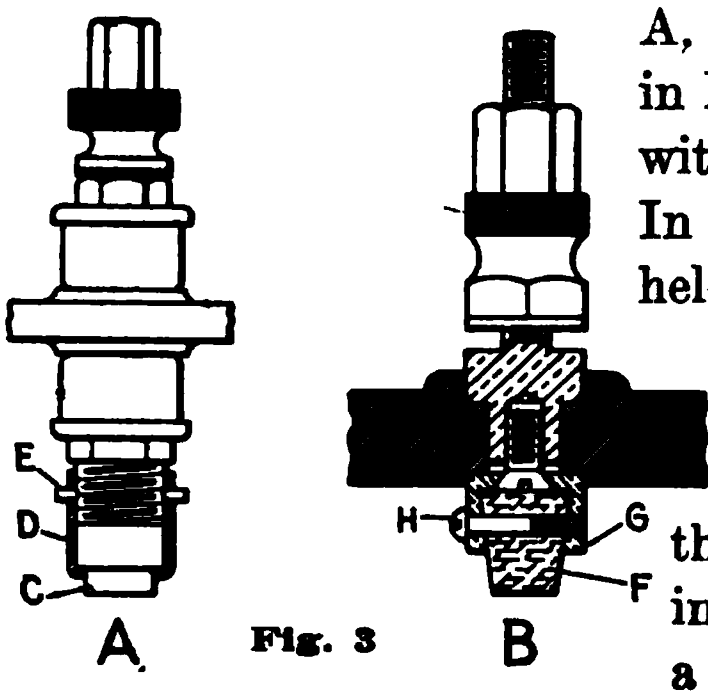


Fig. 3

18. Three *brass stand rods* 25, Fig. 2, are screwed into the base, being employed to prevent the weight of the relay from resting upon the contact fingers, in case the glass ring is broken.

19. To illustrate the operation of a relay and to identify the symbol used to designate this type of instrument on circuit drawings, a bell circuit controlled through the contacts of a relay,* is shown in Fig. 4. The wires and parts of the relay are numbered to correspond with the numbering given in Fig. 2. The back contact is not used, the circuit being controlled only through the front contact 24.

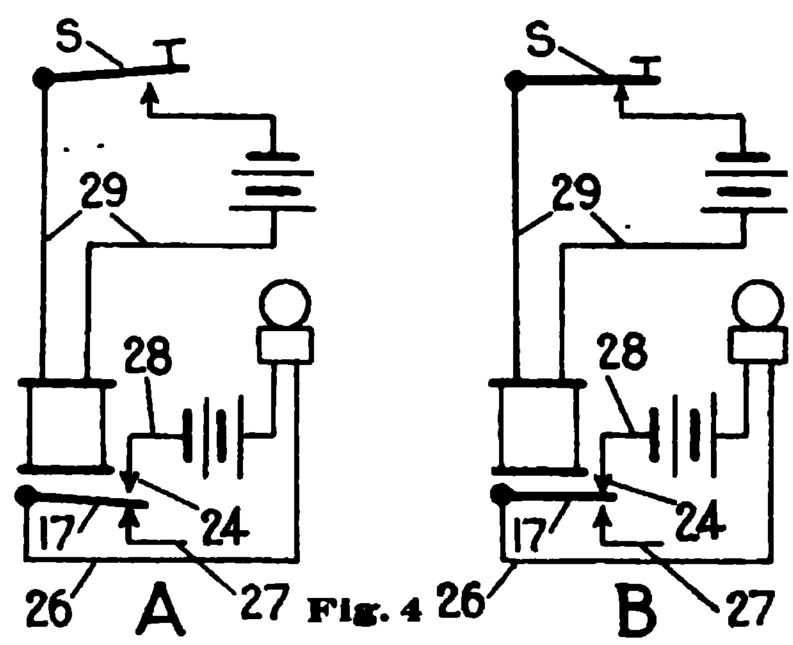


Fig. 4

Sketch A in which the relay circuit is broken by key S, and consequently the relay de-energized and the armature down, represents the relay with its contacts in the position shown in Fig. 2. As the bell circuit is broken through the front contact the bell will not ring unless key S is closed as indicated in sketch B, thus completing the relay circuit and energizing the relay, consequently raising the contact finger 17, and completing the bell circuit through the front contact.

*It should be remembered that although in describing the application of this and other relays, bell circuits are used, other instruments are controlled by relays.

20. It is apparent that an ordinary failure of a relay circuit, such as a broken wire, etc., will cause the armature to drop, and therefore, circuits, the safe operation of which depends upon this action of the armature, are usually controlled through the *front* contacts.

When a path through the *front* contacts of a relay is completed, the magnet being *energized,* the relay is said to be **closed,** and when this path is broken, the magnet being *deenergized*, the relay is said to be **open.**

Fig. 5

21. A **neutral relay,** which differs slightly in construction from that shown in Fig. 1, is illustrated in Fig. 5. As indi-

Fig. [illegible]

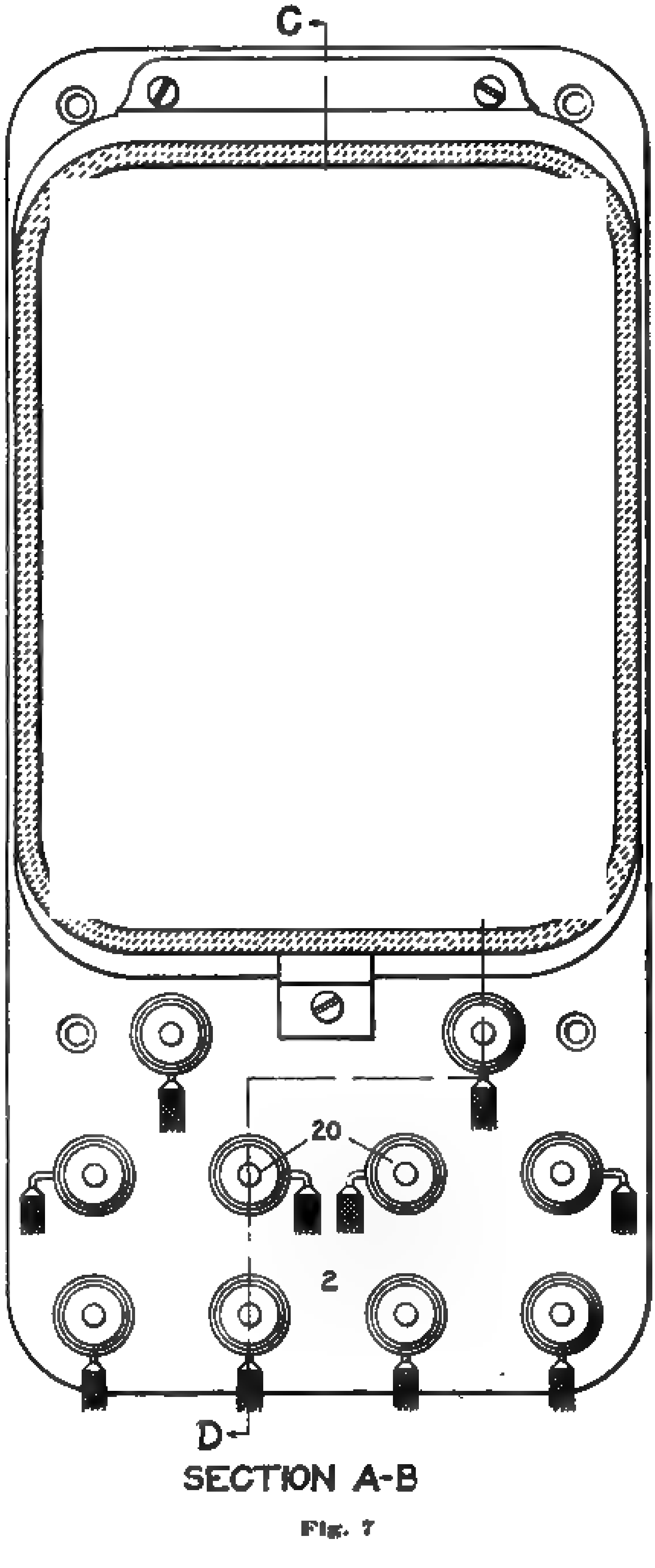


Fig. 7

SECTION C-D

Fig. 7

cated the base and tray are square, being fitted with a square glass employing felt instead of rubber gaskets.

22. The pivoted ends of the contact fingers are attached to the binding posts by braided stranded wire, instead of by copper strips.

The coils are *form wound** and can therefore be removed without disturbing the operating parts of the relay.

The construction of the back contact posts should be observed.

23. In Fig. 6 is shown a **wall type neutral relay,** which is arranged to be screwed to a suitable support, being designed to operate when placed in a vertical position.

The base is made of slate or porcelain, the latter material being more commonly used. On this account further insulation is of course, unnecessary. The glass case was omitted on the early designs, but is now generally employed. The coils are *core wound.* A plan view and a section of the relay are given in Fig. 7.

24. The coils 1, are rigidly secured to the base 2, by means of the *magnet stand* 3, which is screwed to the base and to which the back strap is attached, and also by means of the *porcelain supporting spectacle* 4, which is attached to the base with two screws 5.

25. It will be noted that the movement of the *armature bar* 6, is limited by the *front* and *back stop screws* 7 and 8 respectively, the former taking the place of the armature stop (Art. 13), and the latter acting as a stop to keep the armature from falling too far from the pole pieces when the relay is de-energized.

A *retractile spring* 9, which is secured at one end to the armature bar as shown, and at the other end by means of fine silk cord to a *tension post* 10, is used to assist in drawing the armature away from the magnet, when de-energized. The *knurled* thumb-piece 11, is rigidly fastened to the *swivel shaft* 12, so that when the thumb-piece is turned, the silk cord will

*See **Magnetism and Electricity,**—*Electromagnetism.*

wind or unwind on this shaft, thus increasing or decreasing the tension of the retractile spring as desired, to obtain the proper operation of the armature.

26. The *aluminum contact fingers* 13, are provided with platinum contact points, and are attached by nuts to *bone studs* which are screwed into the armature, the pivoted ends of the fingers being connected to the binding screws 14, by flexible copper strips.

27. The *front contact springs* 15, and the *back contact springs* 16, are made of German silver, carbon or graphite blocks (sometimes silvered) being soldered to the front contacts, and pieces of platinum to the back contacts. This arrangement provides platinum to graphite for the front contact points, and platinum to platinum for the back contact points. The springs are riveted to brass pieces 17, which in turn are attached to brass clamps 18, that are adjustably mounted upon the supporting spectacle. The portion of the contact spring which is secured to the brass base 17, is slotted to permit of its adjustment. Adjusting screws 19, are employed to secure *fine* lateral adjustment. Thus it is apparent that the contact springs may be adjusted laterally and vertically.

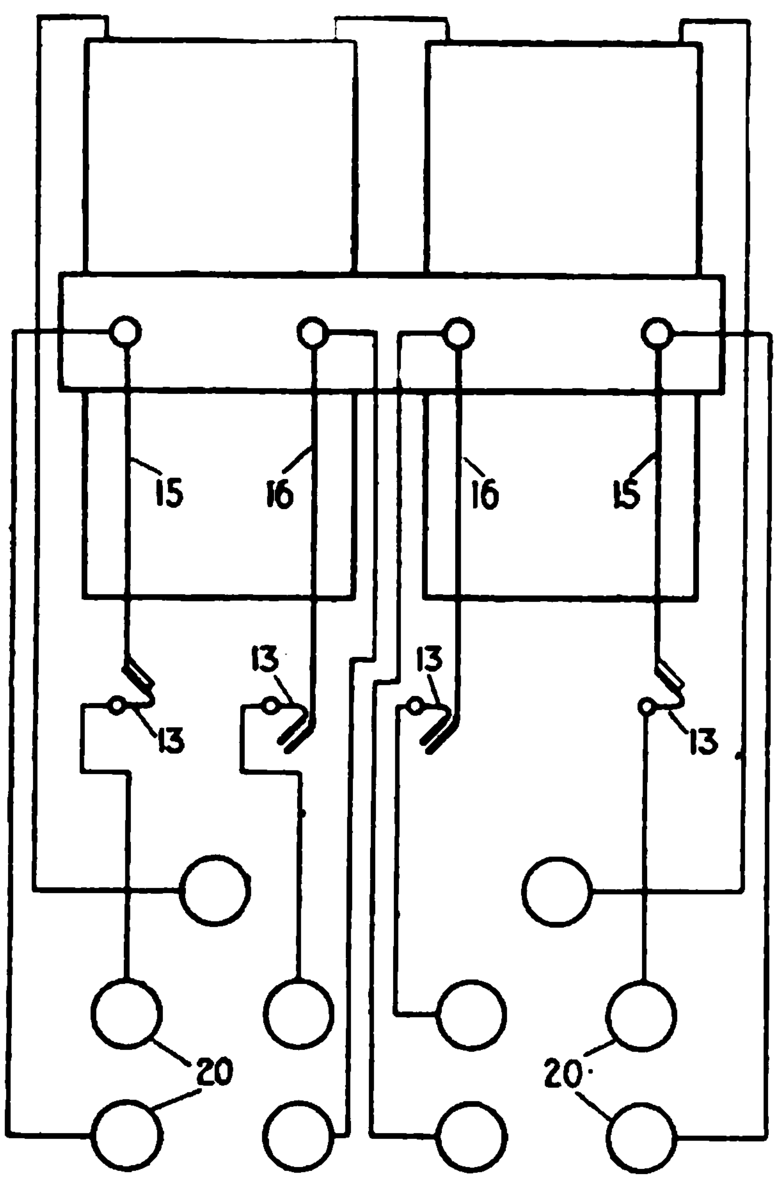


Fig. 8

28. A wiring diagram for the relay illustrated in Figs. 6-7, is shown in Fig. 8. This shows the wiring between the coils 1, contact fingers 13, springs 15 and 16, and binding posts 20. As shown these connections are all run in grooves on the back of the base, the wires for the operating and controlled circuits being carried to the binding posts, as indicated in Fig. 7.

29. The relay illustrated in Fig. 9 is of the **neutral type**, being generally similar to that shown in Fig. 1.

Fig. 9

The base and tray are made from insulating material, moulded to the proper shape.

The coils are wound on spools and consequently can be removed without disturbing the operating parts. The cores are rigidly attached to the base, thus giving the required support to the coils.

30. In Fig. 10 is shown a **neutral relay** which differs slightly in design from those heretofore described. As will be seen it is of the wall type, being arranged to be mounted on a suitable support by means of brackets 1. The *long* binding posts 2, are used in the position shown, in order to make them easily accessible. Bracket 3, which is attached to the back

strap and supports the coil terminals, is made of insulating material

Fig.

31. In Fig. 11 is illustrated what is known as a **mercury contact neutral relay.** The name is derived from the method

Fig. 11

employed to open and close the controlled circuits, this being accomplished by *mercury*, enclosed in hollow *glass rings*, which are given a rotary motion by the operation of the armature.

32. A diagram of the operating parts of the relay, with the coils de-energized, is given in Fig. 12.

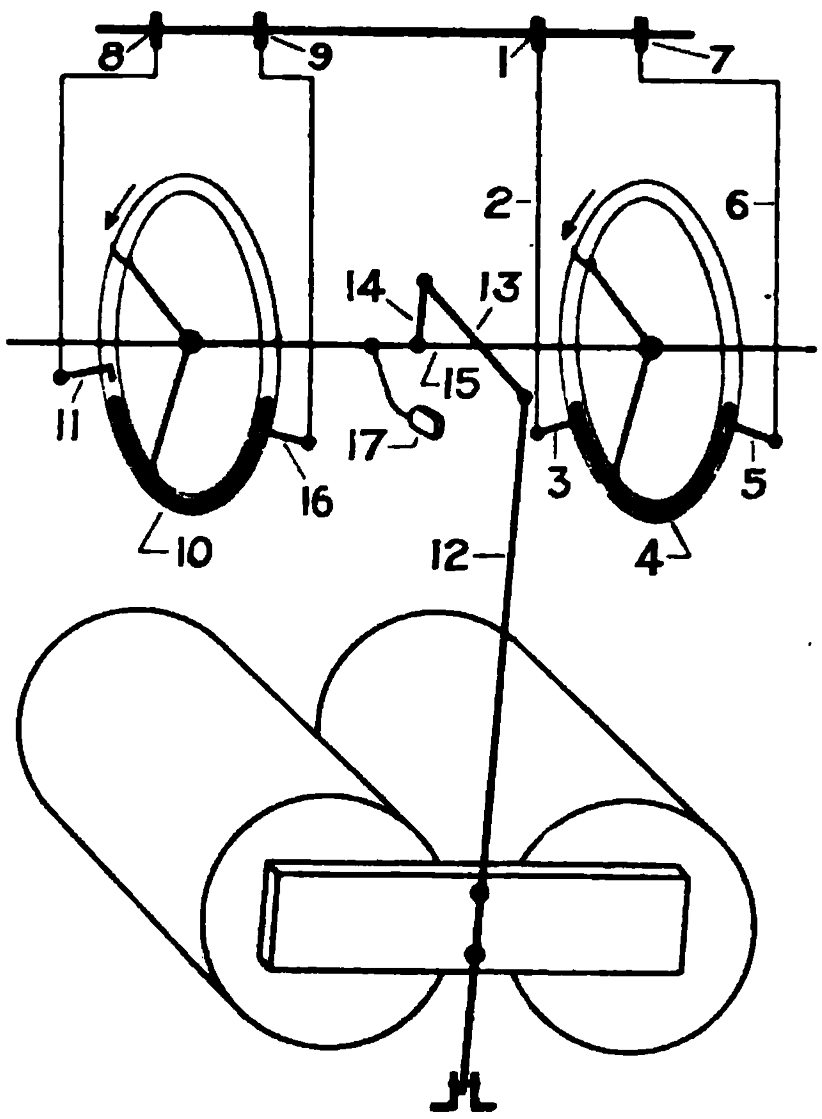


Fig. 12

It will be noted that, with the parts in the position shown, a path for a circuit is completed from binding post 1, through connecting wire 2, to a *platinum contact* 3, which passes through the glass ring 4, into the mercury. From contact 3, the circuit is carried through the mercury to contact 5, through connecting wire 6, to binding post 7. It will also be noted that as *platinum contact* 11 is not immersed in the mercury, the path from binding post 8 to 9, is interrupted.

33. Now when the armature is attracted to the magnet, *armature lever* 12, through the medium of *link* 13, and *crank* 14, gives a rotary motion to *shaft* 15, and consequently to the *mercury rings*. This movement of the rings causes contact 11, to be plunged into the mercury, and also causes contact 5, to be withdrawn from it. As contacts 3 and 16, are at all times, immersed in the mercury, this movement of the rings completes a path for a circuit through ring 10, and opens the circuit in ring 4.

From the foregoing it is apparent that the connections to ring 4, form a *back contact*, and those to ring 10, a *front contact*.

The counterweight 17, is provided to restore the mercury rings to the position they occupy when the relay is de-energized,

the arm supporting the counterweight being bent so as to make the weight most effective when the relay is energized.

34. In cases where circuits carrying *considerable current,* are to be controlled through relay contacts, the type of **neutral**

Fig. 13

relay illustrated in Figs. 13-14 is employed.* The diagram, Fig. 14, shows the circuit arrangement. The armature lever 1, which is pivoted at point A, is counterweighted so as to raise the armature lever, and thus open the controlled circuit, when the relay is de-energized. *Heavy carbon contact blocks* 2, are fastened to the end of the armature lever and to the contact post 3, these being necessary on account of possible arcing when breaking the heavy current which is carried through them. The contact post 3, consists of an iron core around which is passed a few turns of insulated copper wire, forming a path for the controlled circuit. This is so

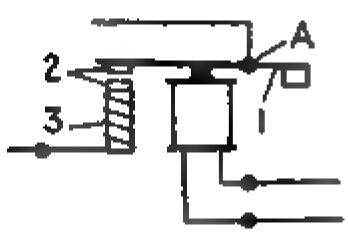


Fig. 14

*It will be observed, by referring to the list of symbols in **Drawing**, that the symbol for this relay differs from that used to designate other neutral types.

arranged in **order that any arc, which may form when the** contacts open, will be extinguished by the **magnetic flux.***

INTERLOCKING RELAYS

35. In Fig. 15, is illustrated one type of **interlocking relay.** This consists essentially of two neutral relays mounted on one

Fig. 15

base, each set of coils being supplied with current from a separate source of energy. The coils of this relay are *form wound.*

36. To the armatures 1 and 2, are attached *projecting arms* 3 and 4, upon the ends of which are riveted *lugs* 5 and 6, carrying *rollers* 7 and 8. The projecting arms, through the medium of *pawls* 9 and 10, *interlock mechanically* with one another, being so arranged in order to *permit* or *prevent* contact points 11 and 12, making electrical connection with back contact posts 13 and 14.

*See *blow-out coils* **Magnetism and Electricity,**—*Electromagnetism.*

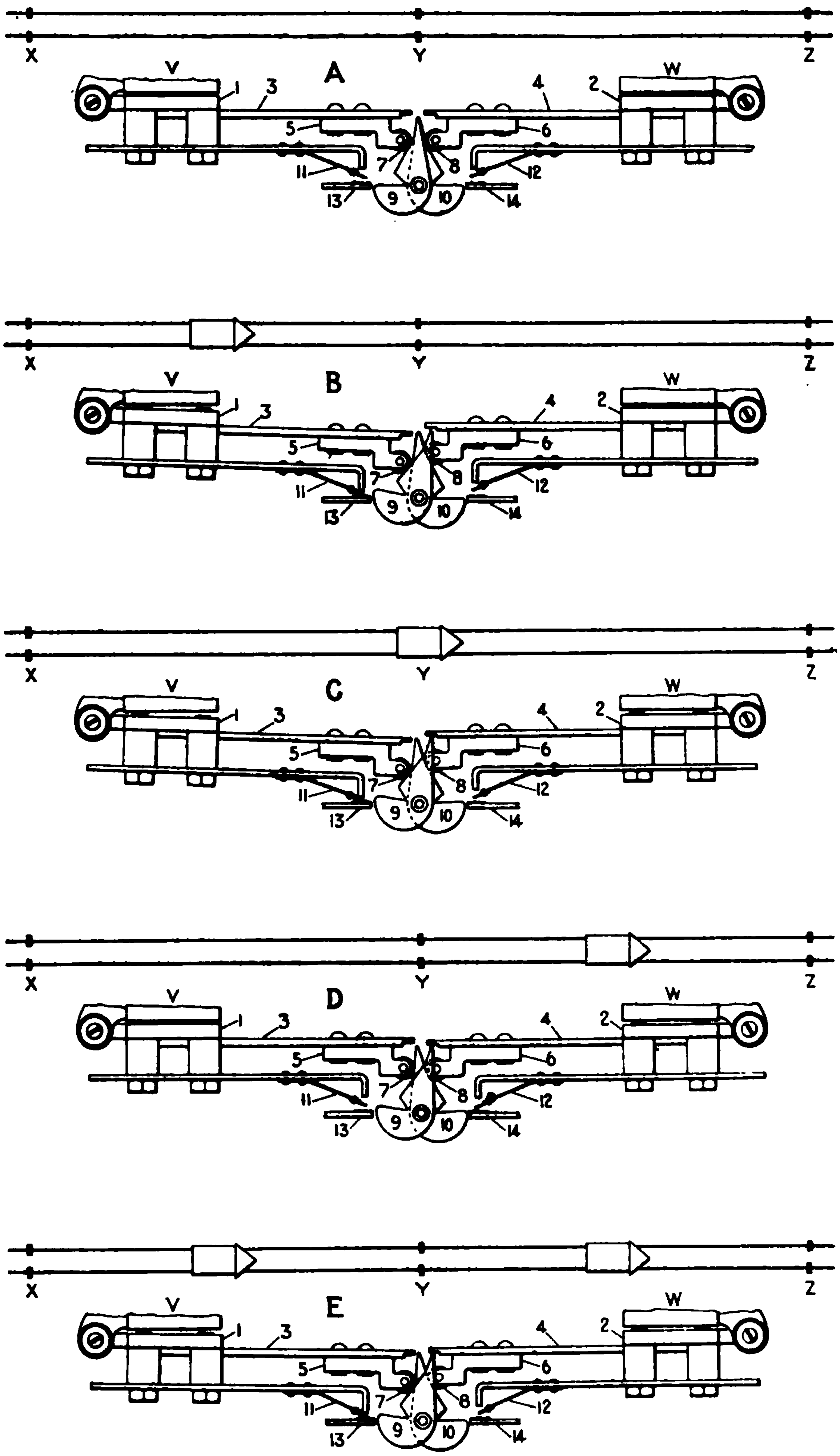


Fig. 16

37. The sketches shown in Fig. 16, illustrate the operation of this relay, the numbering of the parts corresponding with that given in Fig. 15.

As ordinarily arranged, the presence of a train on a given section of track, controls the current passing through the coils of the relay. With this in view the sketches are arranged to show the action of the armatures, pawls, etc., while trains are passing over the length of track controlling the relay.

38. The circuits controlling coils V and W, are arranged so that when a train is on any portion of the track between points X and Y, coils V will be de-energized and when on the portion of the track between points Y and Z, coils W will be de-energized. If a train spans point Y, thus being on both portions of the track, *both* coils will be de-energized. This condition is of course, the same if there are two trains, one on each portion of track.

39. When there is no train on the track as shown in sketch A, both sets of coils are energized and consequently their armatures are raised and back contacts 11—13 and 12—14, are open.

When a train enters the portion of track between points X and Y, sketch B, the current passing through coils V, is reduced to an amount that is insufficient to hold up their armture, which drops, completing a path through contact 11—13, and also by means of roller 7, moves pawl 9 into a position beneath projecting arm 4, as shown.

When the train spans point Y, sketch C, coils W will be de-energized and projecting arm 4, will drop onto pawl 9, thus preventing the closing of back contact 12—14. As the train passes off that portion of the track between points X and Y, sketch D, the normal amount of current again flows through coils V, the armature of which picks up and breaks the controlled circuit at contact 11—13. It will be observed that although roller 7, is raised off pawl 9, the friction between this pawl and projecting arm 4, overcomes the force of gravity which tends to return it to its normal position (sketch A), and therefore contact 12—14 is still held open.

When the entire train has passed point Z, the operating parts of the relay assume the position shown in sketch A.

40. Sketch E is given to illustrate the effect of a train on each section of track, both having entered from the left. It will be noted that the position of the relay is a duplication of that shown in sketch C.

It will be observed that a train moving in the opposite direction will produce the reverse operation, that is, contact 12—14 will be closed, and contact 11—13 held open by pawl 10.

41. To illustrate the use of this type of relay, and to identify its symbol, the bell circuit shown in Fig. 17, is given. When there is no train on the track as in sketch A, Fig. 16, the bell circuit is broken, but immediately a train enters as in sketch B, contact 11—13 completes the circuit and the bell rings. The bell continues to ring until the train has entirely passed point Y, as in sketch D, at which time the circuit is again broken at contact 11—13.

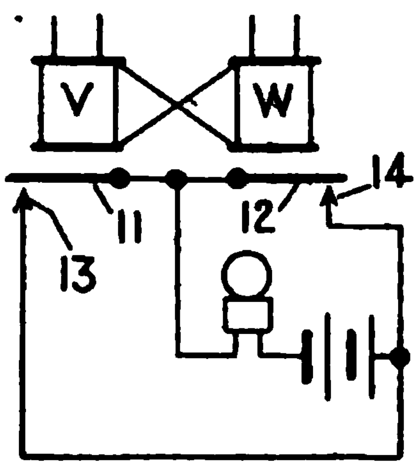


Fig. 17

42. A study of Figs. 16 and 17, will indicate that, irrespective of the direction in which the train is traveling, the bell circuit will be completed only until the train has entirely passed point Y.

43. With these types of relays the principal circuits are controlled through the back contacts, although front contacts are generally provided, being used under special conditions.

44. An **interlocking relay** in which the armatures employ a different method of interlocking, from that shown in Figs. 15-16, is illustrated in Fig. 18. The operation of the relay is illustrated diagrammatically in Fig. 19.

45. As indicated the armatures pivot on the *inner side* of the coils. Two projecting arms 1, carrying *back* contacts 2,

extend obliquely from the armatures and, meeting in the center, are arranged to interlock with one another by means of small

right angle hooks formed on the end of each projecting arm.

In view of the description given in connection with Fig. 16, the sketches shown in Fig. 19, are self-explanatory.

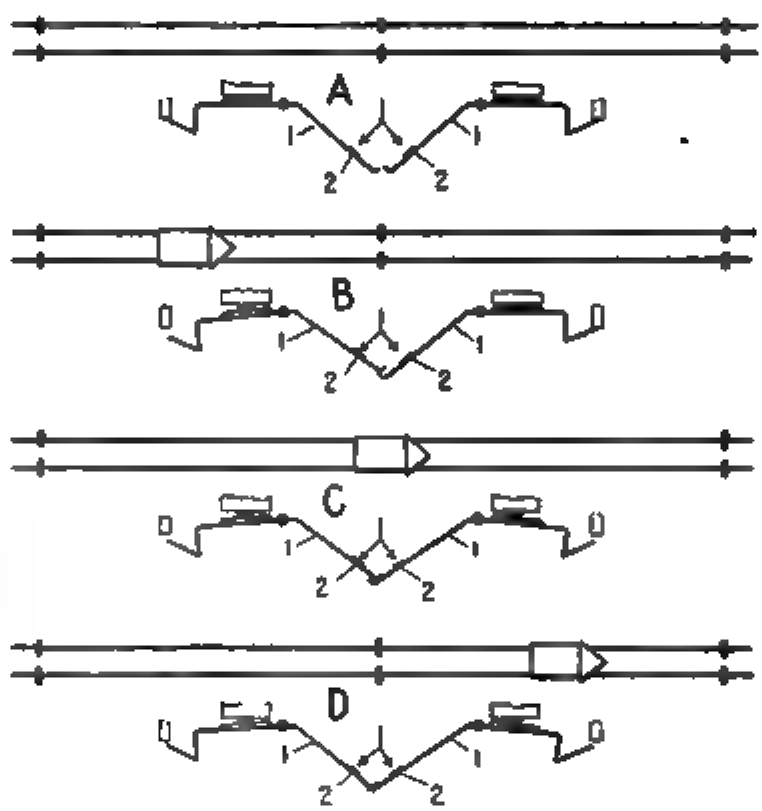


Fig. 19

46. The proper air-gap between the pole pieces and armatures is maintained by the back contacts. These are adjusted either by raising or lowering the entire back contact post, or by adjusting either of the contacts by means of the adjusting screws.

47. A type of **interlocking relay** that has been used to a considerable extent is shown in Fig. 20. It is designed to be

Fig. 20

operated when placed in a vertical position, with the interlocking arms *upward*. The relay is shown reversed in order to more clearly illustrate its operating parts.

48. The base is made of slate or cast iron, the latter material being more commonly used. When an iron base is employed the binding posts, etc., are suitably insulated from it.

49. The coils 1, which are core wound, are held in position by magnet stand 2, which is secured to the back straps and to the base, and by brass supporting spectacles 3, which are firmly attached to the base. Adjusting screws 4, are provided to change the position of the magnets, moving them toward or away from the armatures 5.

50. Upon the aluminum armature bars 6, are mounted German silver contact springs 7, and phosphor bronze interlocking hooks 8, the former being riveted to the armature bars to insure good electrical connection, and the latter being insulated from them, by means of thin sheets of mica 9. Into the points of the back contact screws 10, are soldered platinum wires to insure good electrical contact with platinum discs soldered onto the contact springs. It will be observed that stops are provided on the armature bars 6, to limit their motion, and also that of the springs 7.

51. When either pair of coils are de-energized the path for the controlled circuit is as follows: From binding post 11, through connecting wire 12, to back contact screw 10; thence, through contact spring 7, armature bar 6, and connecting wire 13, to binding post 14.

As the brass spectacles 3, are not insulated from the metal base, and as the armature bars are in electrical connection with the armature shafts 15, these shafts must be insulated from the spectacles. This is accomplished by the use of *glass jewels* which are fitted into the *jewel screws* 16, and securely held in place by *hard rubber caps* 17.

The operation of the relay depends considerably upon the adjustment of the retractile springs 18.

52. The interlocking of the armature bars is the same as in Fig. 19.

Front contacts and additional back contacts are sometimes provided with this relay.

53. In Fig. 21 is shown a type of **interlocking relay,** the interlocking feature of which differs considerably from those previously described. This is illustrated by Figs. 22 and 23,* which represents conditions similar to those described in connection with Fig. 16. With no train on the track, as shown by sketch A, back contacts 1 and 2, are raised off back contact post 3. When a train enters as indicated in sketch B, back contact 1, drops onto the back contact post and completes the bell circuit. When the train takes the position indicated in sketch C, back contact 2 drops *on top* of back contact 1, so that when the train proceeds to the position shown in sketch D, the coils controlling the operation of back contact spring 1, are energized and consequently this spring raises spring 2 out of electrical contact with the back contact post, thus breaking the bell circuit.

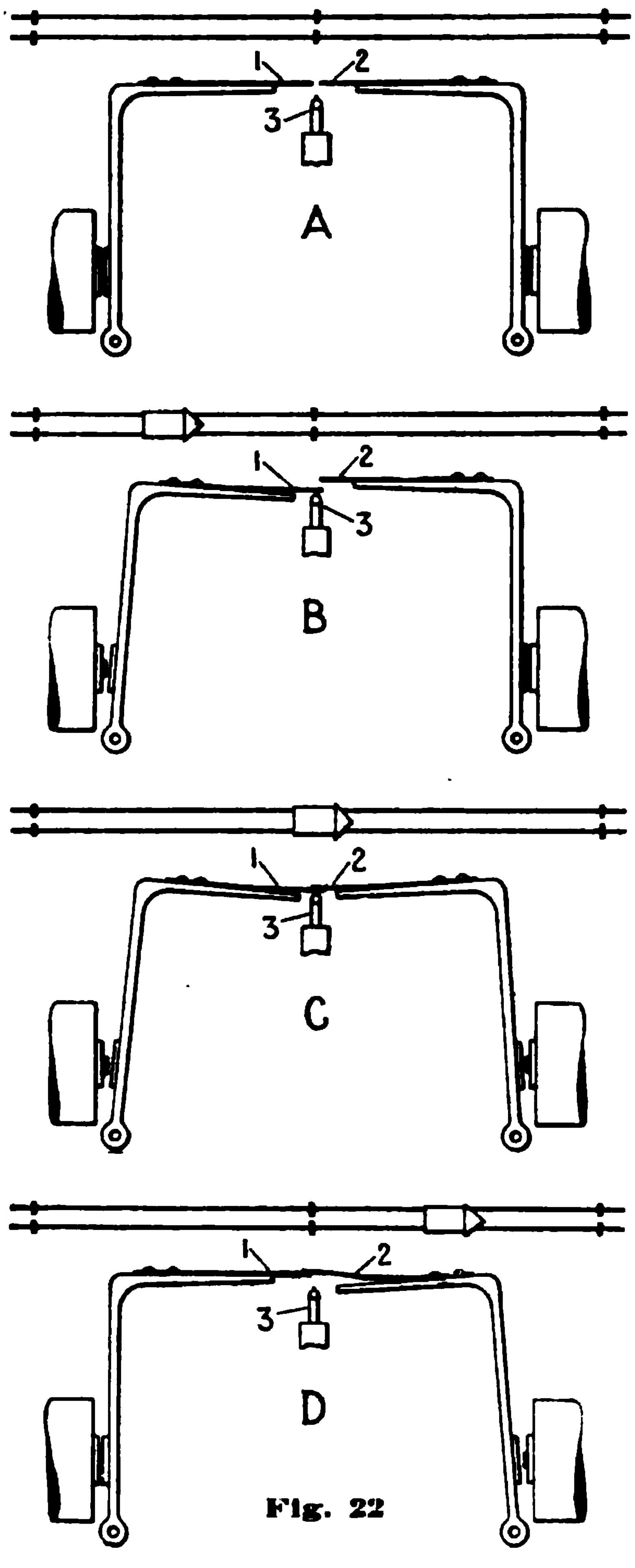
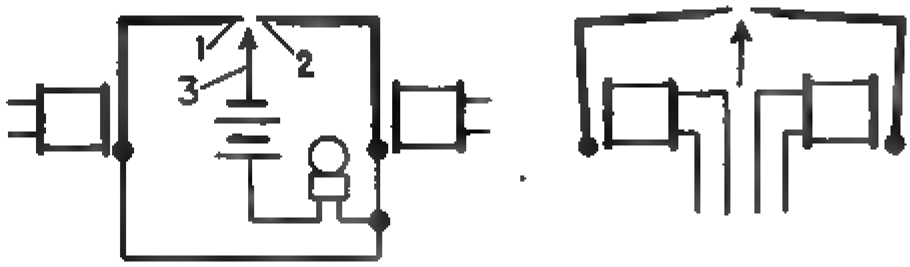


Fig. 22

This relay is sometimes provided with additional contacts. Also, in some cases, a bone insulator is mounted on the upper or lower side of one of the contact springs, so that this spring will be insulated from the back contact

*Although in many cases, the ordinary symbol for interlocking relays is used for this type of relay, the symbol shown in Fig. 23, sketch A, is, in some instances, employed. Sketch B shows the symbol employed, when the relay is constructed with the armatures on the outside instead of the inside of the magnets, the relays being normally de-energized.

post or from the other contact spring in certain positions of the relay.



A **Fig. 23** B

54. An old type of **interlocking relay,** sometimes called a *double circuit instrument,* which is used to some extent at the present time, is illustrated in Fig. 24.

Fig. 24

The binding posts, etc., are suitably insulated from the base, which is made of cast iron. As separate circuits are controlled through contacts C—c and D—d, they are insulated from each other.

55. The interlocking of the armature bars is so arranged that when magnet A attracts its armature, the notch in the armature bar of magnet B, will drop and engage with it holding it against the pole pieces. This movement of the armature of magnet A, by means of the pins in the spring bar, reverses springs C—D, completing a path for a circuit through contacts C—c, and breaking a path at contacts D—d. When magnet B is energized its armature bar raises and unlocks the armature bar of magnet A, which is drawn away from the magnet by the retractile spring, thus again reversing the position of contact springs C—D. The center portion of the spring bar is made of insulating material so that the controlled circuits will be insulated from each other.

SLOW RELEASING RELAYS

56. In Fig. 25 is illustrated a **slow releasing relay.** It derives its name from the retarding effect produced upon the releasing of the armature, by the coils.

Copper sleeves or *tubes* are placed over the iron cores, upon these being wound the insulated copper wire. The retarding effect is produced by a current induced in the *secondary* (copper sleeves), when the current in the *primary* (windings) is changing.*

In some cases *short-circuited windings* are employed as secondaries, in place of the copper sleeves.

57. By employing the copper sleeves and a primary of 500 ohms resistance, the armature will be held to the pole pieces from 0.5 to 0.8 sec., after the operating circuit is opened. The use of a secondary winding produces about the same retarding effect. When in service this relay is operated on 10 to 12 volts.

58. This relay is quite similar to that shown in Fig. 1,

*See **Magnetism and Electricity**.—*Electromagnetism*.

although as it is required to control only one circuit, one set of contacts is provided.

Fig. 25

DIFFERENTIAL RELAYS

59. One type of **differential relay** which has been used to a considerable extent is illustrated in Fig. 26. It is constructed of *two sets of coils,* one set being wound to a *higher* resistance

than the other, a combination frequently used being 1 and 22 ohms. Each set of coils has an armature, but the two armatures

Fig. 26

are rigidly connected together. Contacts are attached to the armatures by means of bone insulators, and contact springs are provided as shown. When in service the position of the relay is such, that the armature will not be biased by gravity. From the foregoing it is apparent that a path through the contacts will be opened or closed, according to the position of the armatures, this position being governed by whichever set of coils exerts the greater attracting force.

60. A wiring diagram for this relay is illustrated in Fig. 27, showing the connections between the binding posts and the coils and contacts.

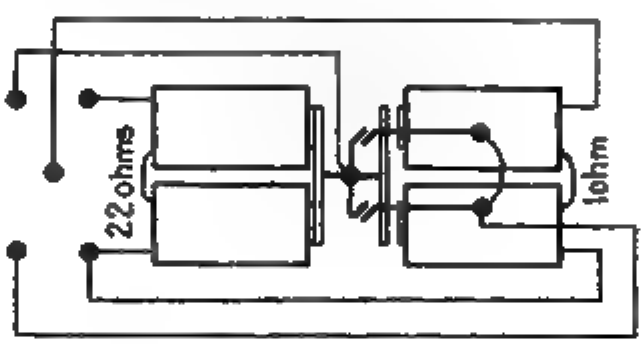


Fig. 27

61. The application of this relay and the symbol employed are shown in Fig. 28. As indicated, coils 1 and 22 are connected in series with battery A. Relay B, which is generally used in connection with this type of relay, is connected *in multiple* with the 22 ohm coil. The current flowing through the low wound coil does not cause

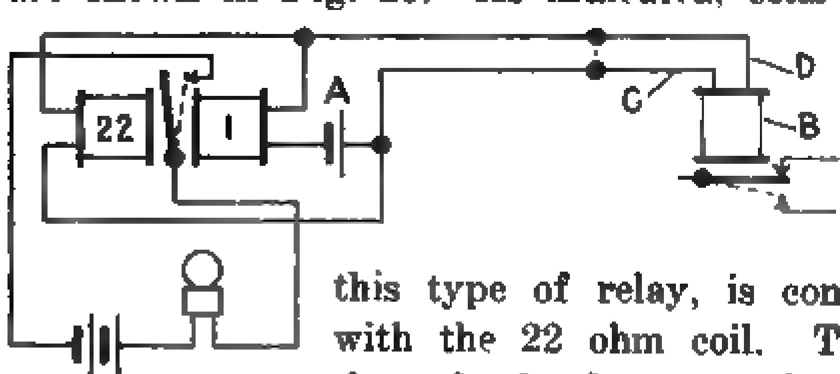


Fig. 28

it to exert sufficient force to overcome that exerted by the high wound coil, therefore, the armature assumes the position shown, the bell circuit being broken. Under certain conditions, a very low resistance path is formed across leads C and D, as shown by the dotted connection, thus shunting relay B and the 22 ohm coil. Consequently, a very small current passes through the high wound coil, the force exerted by it being overcome by that of the low wound coil, causing the armature to assume the dotted position and thus completing the bell circuit. The resistance for relay B is usually not less than 4 ohms.

62. A **differential relay** in which two separate armatures and three pairs of coils are employed, is illustrated in Fig. 29.

Fig. 29

The diagram of connections and the application of this relay are shown in Figs. 30 and 31.

It will be seen that the 1 and 4-ohm coils are connected in series, and that the 12-ohm coils are controlled through a front contact, operated by the 4-ohm coils. The 1 and 12-ohm coils are known as the *differential coils,* and the 4-ohm, as the *neutral coils.* The armature of the former is arranged to swing between the coils, as shown in Fig. 30, being pivoted at the center and having contacts mounted upon its ends, insulated from it, while that of the latter* together with its contacts are arranged to operate as an ordinary neutral relay.

63. The principle of operation of this relay is as follows: The two ½-ohm coils, Fig. 30 (which together constitute the 1-ohm winding), are so wound that when a current is passed through them, *like ends* of their cores will have *like poles,* whereas the two 6-ohm coils (which together constitute the 12-ohm winding) are arranged to have *unlike poles* at any given time. The direction of current in the 6-ohm coils remains *constant,* while that in the ½-ohm coils is *reversed* to operate the differential armature. It will be seen that the back straps, which are separated slightly where they cross, connect the ½ and 6-ohm coils diagonally, thus forming two magnetic circuits. From the foregoing it is apparent that as the armature is pivoted in the center, a current through the 6-ohm coils will exert an equal force on each end, tending to balance it; but, when a current is flowing through the ½-ohm coils, the magnetic flux in the core of one of the 6-ohm coils will be increased, while that in the core of the other 6-ohm coil will be reduced, the armature taking a position in the strongest magnetic circuit.

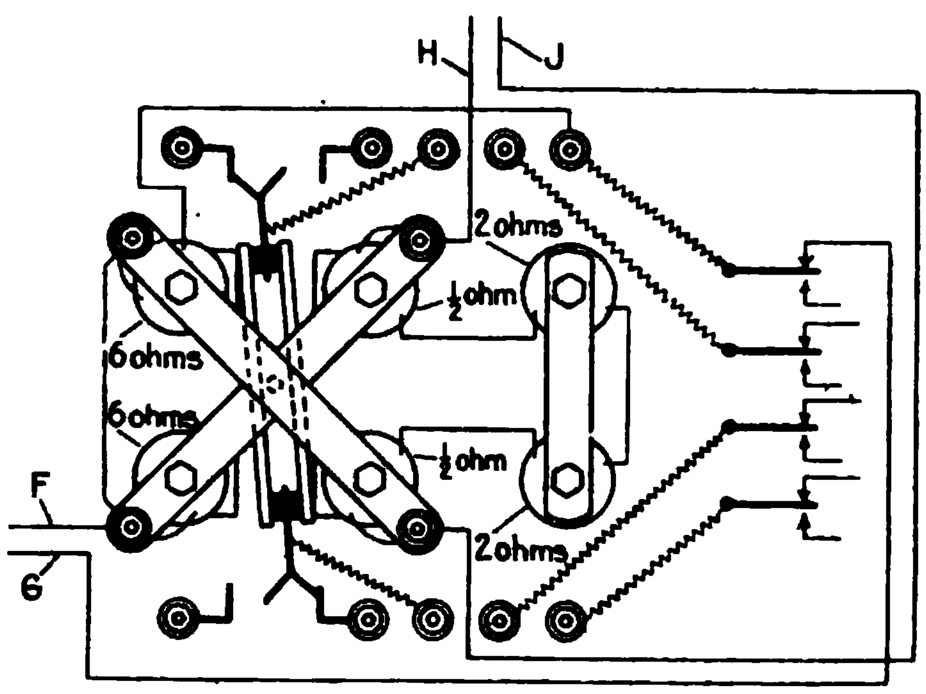


Fig. 30

64. In Fig. 31, current is supplied to the 1 and 4-ohm coils

*The armature is not indicated, the contacts only being shown.

by battery A, through pole changing switch B. It is evident that when this switch is reversed, the direction of current in these coils will be changed, and the differential armature will therefore be attracted to its opposite position, thus opening bell circuit C.

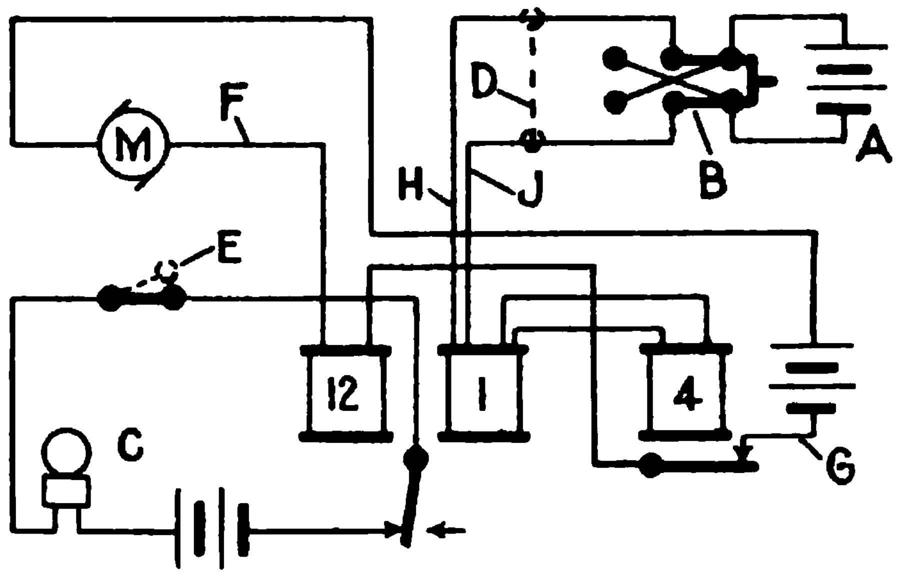


FIG. 31

In some instances a connection, as shown dotted at point D, of very low resistance, practically *shunts* all of the current out of the 1 and 4-ohm coils. This causes the latter to open the circuit of the 12-ohm coils and of the motor.

65. When all of the coils are de-energized as just described, the differential armature remains in the position to which it was last attracted, but, when the circuit of the motor is broken, circuit breaker E, which is operated by it, is opened, and therefore, although the contact on the differential armature may still remain in a position to complete bell circuit C, this circuit will be broken by circuit breaker E.

The three contacts on the neutral armature which were not required to describe the operation of the relay, may be employed to control additional circuits.

COMPOUND WOUND RELAYS

66. The construction of **compound wound relays** is very similar to that of the relay shown in Figs. 6-8, with the exception of the coils. These have *two separate windings,* in some cases one being wound *upon the other,* that is, one half of each winding on each core, and in other cases, one entire winding being placed on *each* core. In the former case the windings are of equal or unequal resistance, such as 16-16 ohms, 24-24 ohms, 20-200 ohms and 100-900 ohms, these resistances

being determined by the manner in which the relay is to be employed. In the latter case, the windings are unequal, generally 8-150 ohms or 12-150 ohms.

It is customary when windings of unequal resistance are placed one upon the other, to wind the high over the low resistance.

67. The wiring diagram for the 16-16 ohm and 24-24 ohm relays, is shown in Fig. 32. This together with the circuits shown in Fig. 33, in which a 16-16-ohm relay is shown, will illustrate how these relays are employed. The controlling wires A to G, Fig. 32, are marked to correspond in Fig. 33.

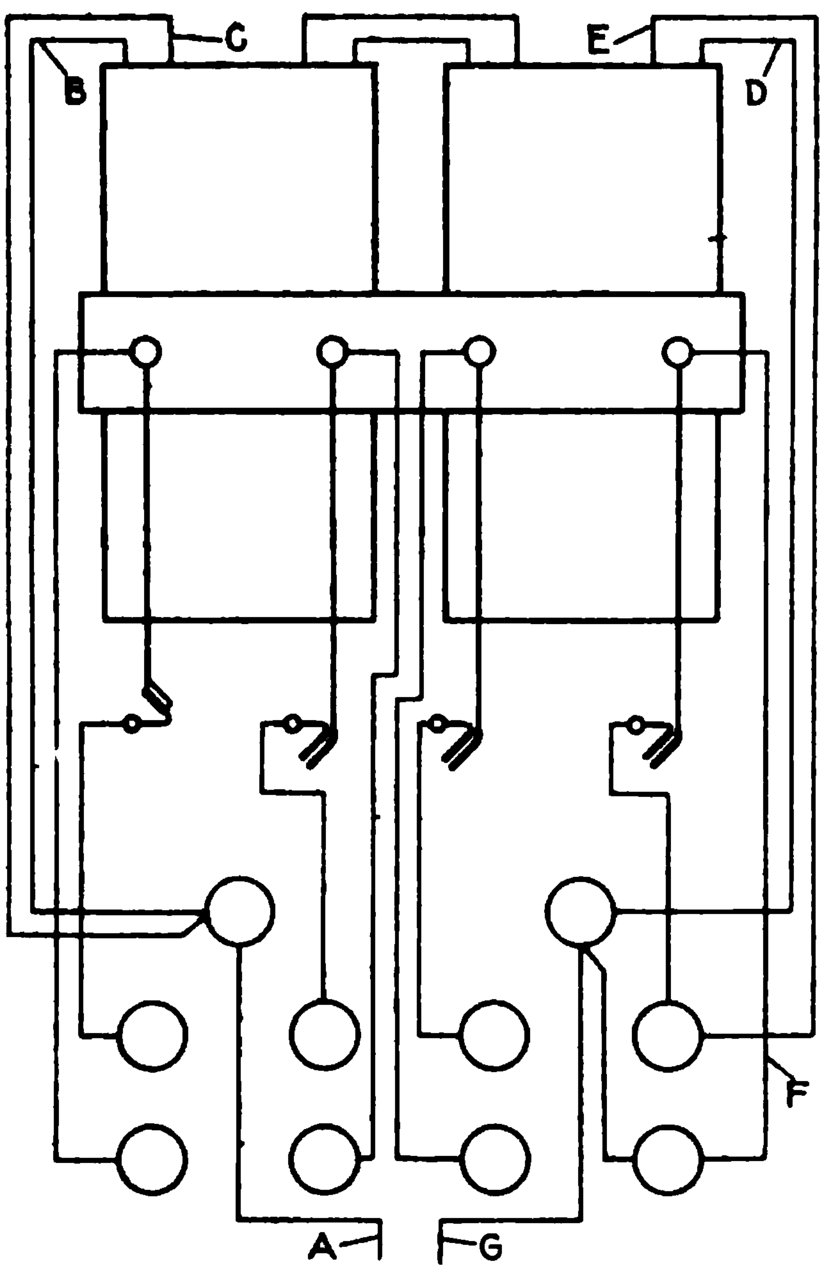


Fig. 32

68. By tracing the controlling circuit, it will be seen that, when the relay is de-energized, the two 16-ohm windings are connected *in multiple*, their combined resistance, of course, being 8 ohms; but as soon as the relay attracts its armature, one of the windings is cut out, by the breaking of the back contact through which it is controlled. It is apparent that when the armature is down a greater number of ampere turns are effective than when it is raised, as in the former case both windings are in circuit. This is so arranged in order that the stronger current may be used to attract the armature and the weaker to retain it.

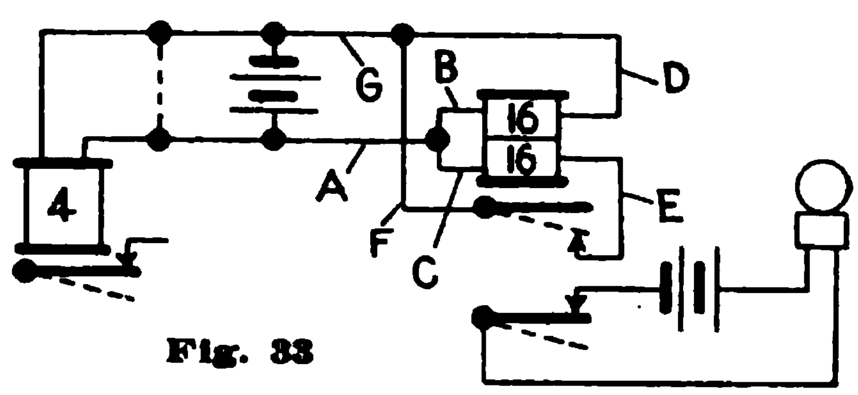


Fig. 33

69. Relay 4, Fig. 33, which is generally used with the 16-16 ohm and 24-24 ohm relays, is connected as shown, the arrangement being such, that under certain conditions, a low resistance path, as shown dotted, shunts the current out of both relays causing them to release their armatures, thus opening the bell circuit controlled by the double wound relay and also, of course, placing the coils of this relay in multiple.

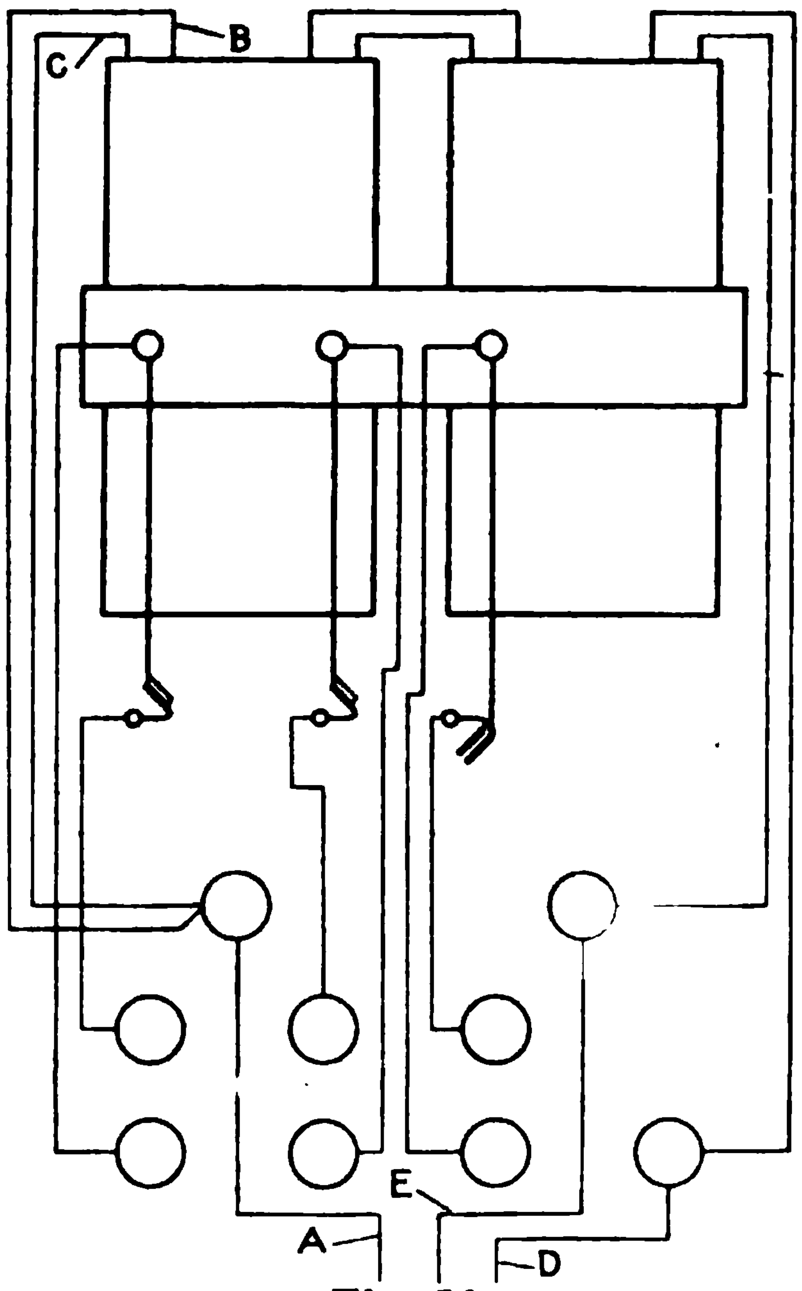


Fig. 34

70. The wiring diagram for the 20-200 ohm and the 100-900 ohm relays, and the circuits showing their adaptation, are illustrated in Figs. 34-35.

Reference to Fig. 35 will show that with switch X open as indicated, the resistance of the relay is 200 ohms, but when this switch is closed the two windings are connected *in multiple,* thus reducing the resistance through the relay to about 18 ohms. The purpose of this is as follows: When current is only passing through the 200 ohm winding, although it will raise its armature and thus complete bell circuit Y, the amount of current flowing will be insufficient to ring bell Z, but when switch X is closed the increased current flow, due to the decreasing of the resistance to about 18 ohms, will also cause this bell to ring.

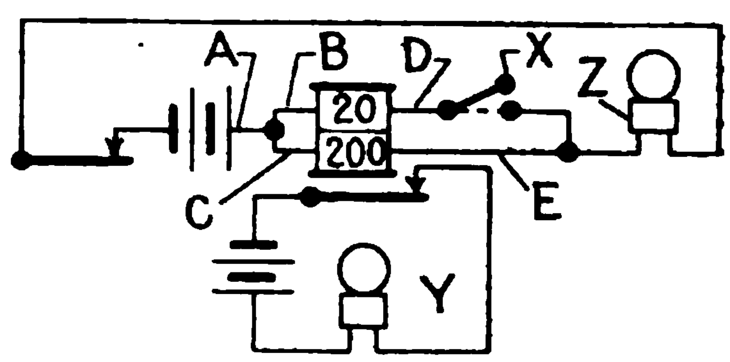


Fig. 35

71. In Fig. 36 is given a wiring diagram for the 8-150 ohm and 12-150 ohm relays. The object of these combinations is

described in connection with Fig. 37, which employs an 8-150 ohm relay.

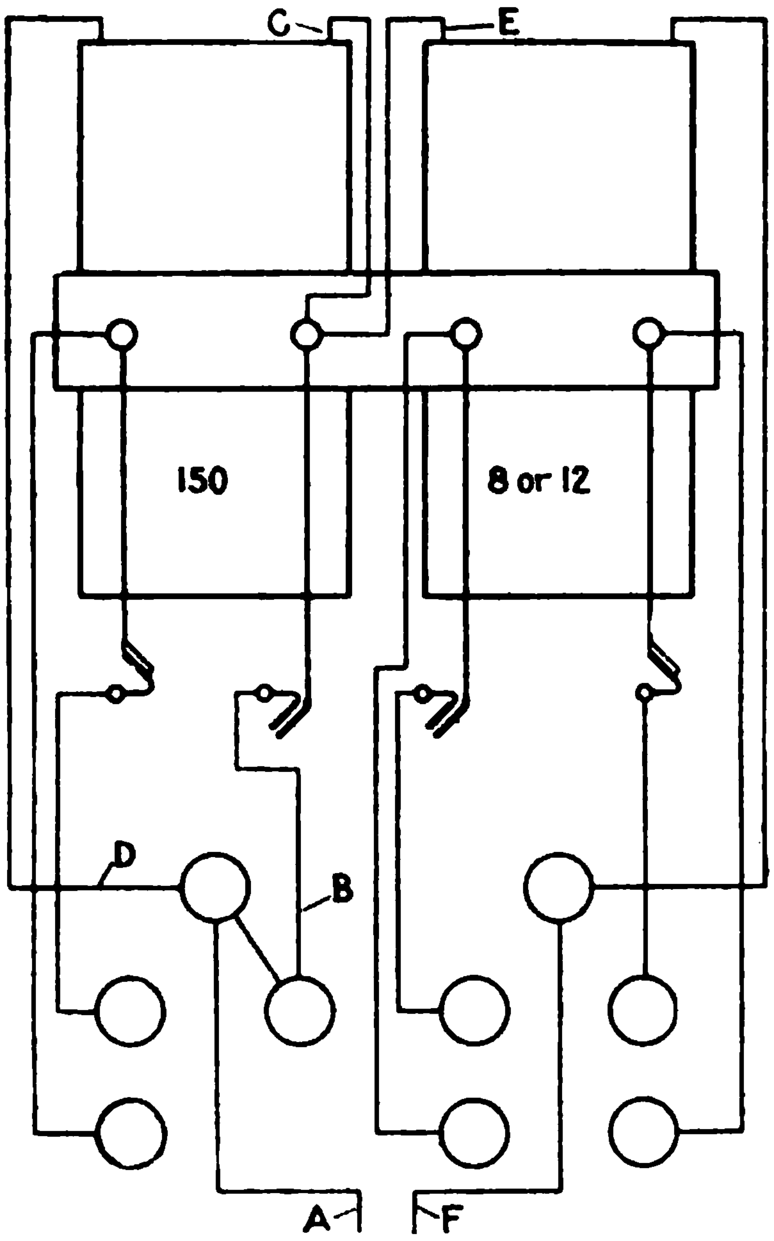


Fig. 36

It will be observed, in sketch J, that when the relay is de-energized, the 150 ohm winding is shunted out of the circuit, thus the resistance of the path through the relay is 8 ohms; however, when the relay is energized as shown, the two windings are placed in series, thus raising the resistance to 158 ohms.

Another method sometimes used for connecting up this relay is illustrated in sketch K, the wiring, of course, being changed from that shown in Fig. 36. When thus arranged the two coils are in multiple when the relay is de-energized, their combined resistance being about 7.59 ohms, and when energized the circuit through the 8-ohm coil is broken, the relay then having a resistance of 150 ohms.

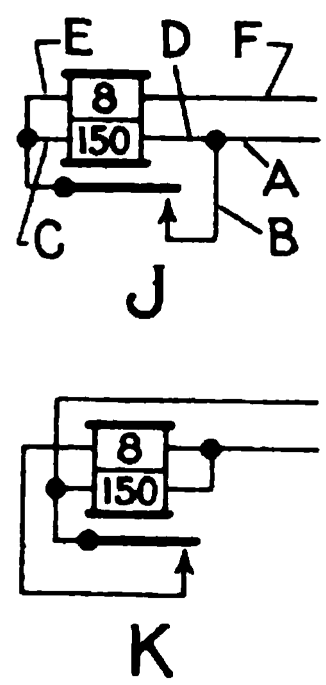


Fig. 37

The purpose of these combinations is to save energy while the relay is closed, a smaller current sufficing to hold up the armature, than is required to pick it up.

SOLENOID RELAYS

72. In Fig. 38 is illustrated one type of **solenoid relay.** With this device the core is withdrawn by the retractile spring, when the coil is de-energized. With some types the arrangement is such, that the core is withdrawn by gravity.

73. The *guide arm* 1, acts as a support and guide for the core. The *key* 2, which is securely fastened to the guide arm, travels in the *slot* 3 in the upper extension of the core, preventing the core and consequently the *contact bar* 4, from turning and thus insuring the proper alignment of the *carbon contact blocks* 5—6.

Fig. 38

74. The *brass contact pieces* 7, and the carbon contact blocks 6, are electrically connected by means of the *flat bronze springs* 8. The contact pieces and springs are mounted upon blocks 9, of insulating material, thus being insulated from the iron case.

75. When the coil is energized and the core drawn into it, contact blocks 5, make contact with blocks 6, and contact spring 10, with contact pieces 7, thus completing two parallel paths for the controlled circuit.

76. A high voltage circuit is generally broken through these contacts and as the resistance of the carbon contacts is usually quite high, the additional path through the contact spring is provided. On account of the high voltage controlled, there is a tendency to arc, and it is for this reason that the carbon contacts are provided, these contacts making *before* and breaking *after* the metal contacts.

The contact bar 4, and contact spring 10, are of course, insulated from the core, this being accomplished by means of a bushing and washers of insulating material.

POLARIZED RELAYS

77. In Fig. 39 is illustrated a type of **polarized relay,** which is similar to the *neutral relay* shown in Fig. 5, with the exception of the addition of the *polarized feature.*

Fig. 39

78. A bottom view of the base of this relay, with the neutral armature and contact fingers removed, is shown in Fig. 40.*

*The neutral armature and polarized feature operate independently.

This illustration shows the polarized portion of the relay, which consists of *two permanent magnets* A and B, securely fastened to a brass bar C, which is pivoted centrally between the pole pieces N and S. To one end of this brass bar is attached a block of insulating material to which are secured contact fingers D—D′, E—E′; to the other end is attached a weight, to counterbalance the block and fingers, thus preventing the pivot from binding. The magnets, brass bar, etc., are generally called the *polarized armature.**

The contact fingers D and D′ are electrically connected to each other, as also are the contact fingers E and E′, the connections F and G, to the binding posts from each set of springs, being made of flexible stranded wire.

79. It is evident that, in Fig. 40, with current flowing through the coils in the direction to produce N and S-poles** as indicated on the pole pieces, the permanent magnets (the poles of which are marked) will *all* act to cause the magnets to revolve in the direction to produce contact between spring D and contact post H and between spring E′ and contact post J. Now if the direction of current through the coils be reversed, the pole piece marked N will become a S-pole, and that marked S. a N-pole, which condition will cause the polarized armature to reverse its position, thus making contact between springs E and D′ and posts H and J respectively.

Fig. 40

80. Two methods of employing these contacts to control circuits, are shown in Fig. 41, the reference letters corresponding

*Also known as the *polar armature*.
See **Magnetism and Electricity,—*Electromagnetism*.

with those shown in Fig. 40. In sketch A, the contacts are arranged to act as a *pole changer*. For instance, with the contacts in the position shown by solid lines, F is the *positive* wire and G the *negative;* but if the current through the coils is reversed, thus reversing the contacts to their dotted position, F will be the *negative* wire, and G the *positive*. From the foregoing it is apparent, that if another polarized relay be connected to wires F and G, the position of its polarized armature will be governed by the position of springs D—D′, E—E′.

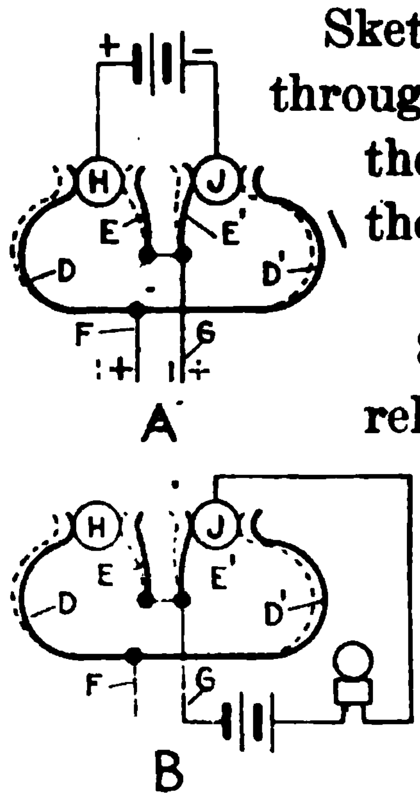


Fig. 41

Sketch B, Fig. 41, shows a bell circuit controlled through one of the contacts (E′). It is evident that the circuit will be opened or closed according to the position of contact E′.

81. The symbol used to designate this type of relay, is illustrated in Fig. 42, the circuits controlled corresponding with those given in Fig. 41.

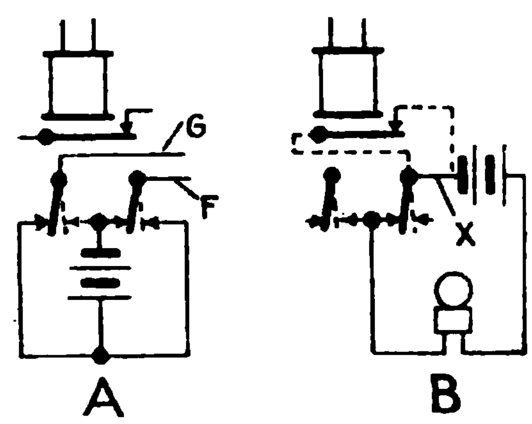


Fig. 42

82. In this type of relay the position of the polarized contacts when the relay is *de-energized* may be varied by adjustment to suit requirements. As ordinarily adjusted the contacts *remain* in the position to which they were *last attracted* making *poor contact,* but when only one polarized contact is employed it can be adjusted so that it will *open* when the relay is de-energized. With the former adjustment, circuits controlled through the polarized contacts, which are required to indicate when the relay is de-energized, must also be broken in series through the *neutral contacts*. This is indicated by dotted lines in sketch B, Fig. 42, wire X of course, being omitted.

83. Another type of **polarized relay,** known as a **neutral polar relay,** which in general design, is similar to that shown in Fig. 6, is illustrated in Fig. 43.

The polarized armature is supported in a vertical position between the coils, being pivoted on two trunnions located at

about the center of the armature. This armature is composed of a permanent magnet, to the upper end of which is attached

Fig. 43

a block of insulating material, to which are secured *two* contact springs insulated from each other. The lower end of the armature swings between the pole pieces of the electromagnet;

consequently upon the polarity of these pole pieces, depends the position of the polarized armature.

Contacts mounted upon blocks of insulating material are fastened to the back strap with screws, one contact being provided for each contact spring.

84. In this type of relay when the electromagnet is de-energized the polarized contacts *remain* in the position to which they were *last attracted*, the one which is closed still making *good contact*.

85. As only two contacts are provided, the pole changing arrangement shown in sketch A, Fig. 42, cannot be employed, this relay being wired for pole changing purposes as shown in Fig. 44. It will be observed that two separate batteries are employed. Wire 5* which connects the contact fingers together, is attached to the binding posts above the base when the relay is installed.

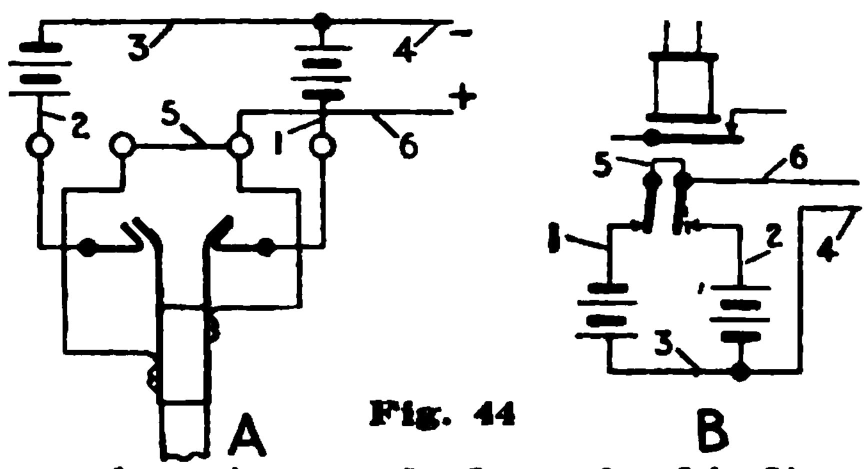


Fig. 44

86. In Fig. 45 is illustrated a **polarized relay** which is developed from the *neutral relay* shown in Fig. 1.

A section taken through the center between the two coils, and an inverted view of the base with the *neutral armature* and *contacts* omitted, is illustrated in Fig. 46.

87. A permanent magnet 1, passes through the base and yoke. The polarized armature 2, upon which the contact springs are mounted, is pivoted between the supporting bracket 3, and the bottom of the permanent magnet.

The magnet is usually arranged with the lower end as the S-pole, a like pole being induced in the polarized armature. It is apparent that, as both ends of the polarized armature are S-poles, the N and S poles produced in the pole pieces 4 and 5, when the coils are energized, will attract one end of the

*Often called a *jumper wire*.

armature and repel the other. This causes it to rotate in a horizontal plane and consequently moves the contact springs 6 and 7 or 8 and 9, into electrical connection with their re-

Fig. 45

spective contact posts 10, this of course, being governed by the direction of rotation and therefore by the direction of current through the coils.

SECTION A--B

SECTION C-D

Fig. 46

It will be observed that the polarized armature is provided with bone stops 11, to prevent it from seating directly on the pole pieces and possibly sticking.

The connections 12, from the contact springs to the binding posts are made of rolled annealed copper strips.

88. The polarized armature contacts when wired for use as a *pole changer*, are shown in Fig. 47. This wiring of course, corresponds with sketch A, Fig. 42.

The jumper wires D and E, are attached to the binding posts above the base, when the relay is being installed.

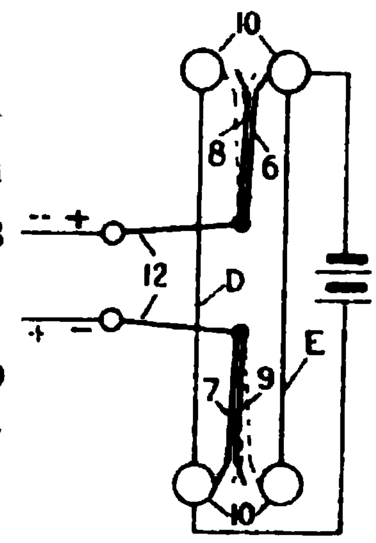


Fig. 47

89. When this relay is de-energized the polarized contacts *remain* in the position to which they were *last attracted,* making *poor contact.*

90. It will be observed that the differential relay described in Arts. 62-65, is of the polarized type.

91. A special type of **polarized relay** is illustrated in Fig. 48. The sketches shown in Fig. 49 illustrate the operation of this device. Sketch A, assumes the controlling magnet 1, to be de-energized and consequently armature 2, operated by this magnet, is released as shown.

The magnets 3 are so wound that when energized, their cores have the same polarity at the bottom, the connecting bar forming a common pole for both. These magnets are *pivoted* at the top, being arranged to swing between the pole pieces of the controlling coils, their position being governed by the polarity of these pole pieces; for instance, if the lower end of the swinging magnets has a N-pole and the direction of current in the controlling magnet is such that the *left* pole piece has a N-pole and the *right* a S-pole, they will of course, exert a force causing the swinging magnets to move to the *right.*

To the upper end of the swinging magnets is rigidly attached a phosphor bronze contact spring 4, upon which are mounted

heavy carbon contact blocks 5—6, lying directly under carbon contact points 7—8. It will be noted that this contact spring is connected by means of a link 9, to the free end of armature 2.

Fig. 48

92. It is apparent that with the controlling magnet de-energized, the circuit for the swinging magnets will be *open*,

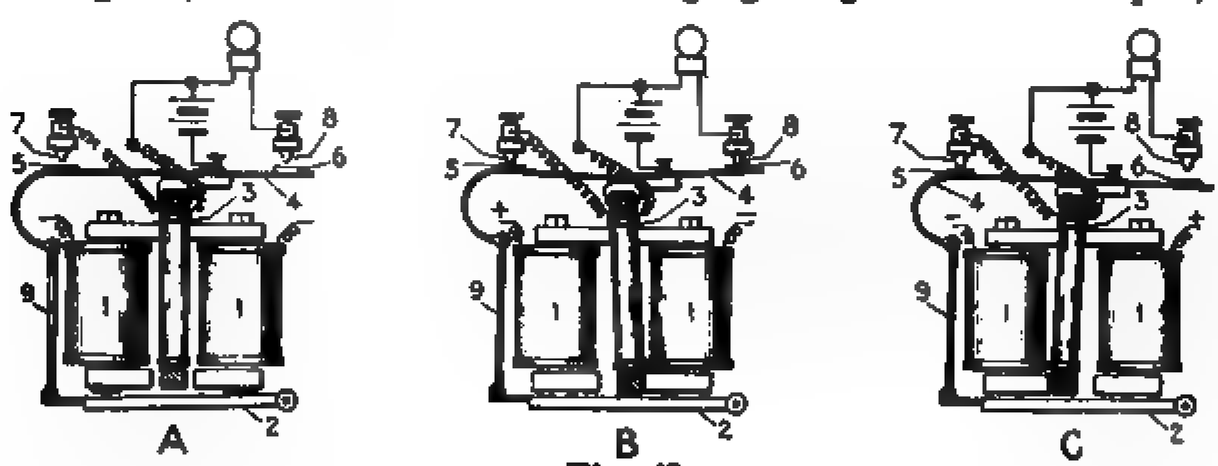


Fig. 49

and these magnets will therefore assume a central position as shown. It should also be noted that under these conditions the bell circuit will be *open*. Now when current is passed through the controlling magnet, their armature is raised and through the medium of the connecting link, the contact spring is also raised and connection is made between contact points 5 and 7, thus completing the circuit of the swinging magnets. If the current through the controlling magnet is in the ***proper direction***, the swinging magnets will be attracted to the position shown in sketch B, thus bending the contact spring, so that contact points 6 and 8 make contact and complete the bell circuit. If, however, the current passes in the ***wrong direction*** through the controlling magnet, the swinging magnets take the position shown in sketch C, thus bending the springs downward, and preventing the bell circuit from closing.

When armature 2 is first raised, with magnets 3 de-energized, there is a tendency to move these magnets to the left, that is, toward the position of safety, as shown in sketch C.

93. The swinging coil, in the position shown in sketch B, has a tendency to bend the left end of the spring downward, and consequently tends to push the armature away from the coils. This assists in *releasing* the armature when the controlling magnet is de-energized.

CONSTRUCTION OF MAGNETS

94. The conditions under which relays are used, subject them, more or less, to lightning discharges. To minimize the effect of these discharges, much better insulation resistance is provided, than in the ordinary types of electromagnets.

95. As before noted some of the relays have *core wound coils*, while others are provided with *form wound coils*.

Copper wire, cotton, silk or enamel covered, is employed for these coils.

A sectional view of part of a *core wound* coil, is illustrated in Fig. 50. To prevent the winding from readily becoming grounded on the core, *three* layers of *Empire paper** *A*, are wound tightly around the core, after which *cord* is wound around the core at each end of the insulating paper, as at point B, in order to fill up any small space between the insulating paper and the magnet heads. Melted rosin is poured on the cord to increase its resistance and prevent moisture from attacking it.

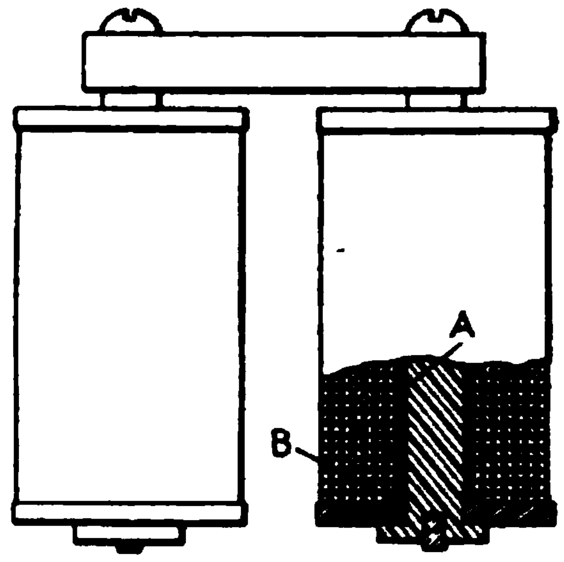


Fig. 50

96. In some cases, when constructing *form wound* coils, after each layer of the winding is completed, it is coated with shellac before the next layer is wound upon it. When the entire winding is complete, the form upon which it is wound, is removed, and the winding wrapped with linen tape. This tape is arranged so that it is *half lapped* on the outside, which causes a *two-third* lap on the inside; thus, there are *two* thicknesses of tape on the outside and *three* on the inside. After the taping is completed the coils are generally impregnated with an insulating compound.

97. The method of connecting relay coils, is diagrammatically illustrated in Fig. 51. If a lightning discharge flows through either of the controlling wires X or Y, to the coils, it would pass directly to the inner winding and then flow *away* from the cores, as indicated by the arrows. This is considered more effective in preventing a breakdown of the core insulation, than when the controlling wires are connected to the outer windings, thus causing discharge to flow *towards* the cores.

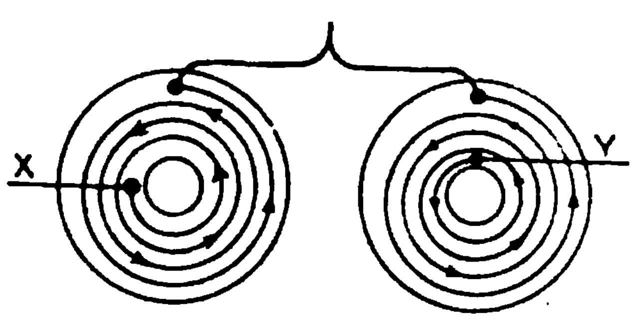


Fig. 51

98. Before winding the coils, it is the common practice, especially where very fine or very heavy magnet wire is used,

*See **Magnetism and Electricity**,—*Electromagnetism*.

to solder a short length of stranded wire to the solid wire, this being used for connecting to the binding post, as the solid wire is liable to be broken when so employed. The stranded wire is of sufficient length to permit two or three turns to be taken around the core, thus providing support for the joint, and of sufficient cross-sectional area to withstand mechanical strain.

99. The wires from the coils are generally attached directly to the binding posts, although in some cases they are soldered to lugs, which are suitable for making the connection to the posts.

100. The exposed portions of the magnet cores, pole pieces, back-straps, etc., of the various types of relays are generally protected from rusting by galvanizing, or by an application of paint, aluminum bronze, etc.

ADJUSTING AND TESTING

101. Adjusting: The operating parts of relays are so adjusted that their armatures will be attracted, that is, *picked up,* when the current through their coils is increased to a given point. This is known as the **pick-up point** of the relay. When the current is reduced to a given point the armature is released, that is, it *drops away* from the magnet. This is known as the **drop-away point** of the relay.

As the resistance of an ordinary relay is a *fixed* value, a given current through the coils requires a given voltage at their terminals, therefore it is apparent that the pick-up and drop-away points of a relay may be expressed in either *amperes* or *volts.* It is also apparent that these points, if desired, may be expressed in *watts.*

As the current through the coils varies in *direct proportion* to the voltage, it is evident that with a given increase or decrease in the voltage, and consequently in the current, the wattage, which is the *product* of these two values, will vary according to the *square* of the variation in voltage or current.

Referring to Fig. 2, it is evident that if the back contact posts are lowered, thus *increasing* the air-gap between the armature and pole faces, the *pick-up point* will be *raised;* and

inversely, if the back contact posts are raised, thus *decreasing* the air-gap, the *pick-up point* will be *lowered.* Furthermore if the length of that portion of the armature stops which extends from the pole pieces, is changed, the air-gap, when the armature is picked up, will be correspondingly changed;* therefore, if this air-gap is *decreased* the *drop-away point* will be *lowered;* and inversely, if *increased,* the drop-away point will be *raised.*

102. In connection with the drop-away point it is evident that when a relay is energized the contact fingers are placed under tension, which assists the armature in dropping. In some cases the drop-away point is adjusted by increasing or decreasing the tension of these fingers.

When two or more contact fingers are attached to an armature, they should be so adjusted that all of the points will make contact at the same time.

103. In some types of relays other methods are sometimes employed to regulate the pick-up and drop-away points. For instance, with the relay illustrated in Fig. 6, the tension of the retractile spring may be adjusted to alter these points.

104. From the foregoing it is apparent that if the armature binds where it is pivoted, thus preventing it from moving freely, the pick-up and drop-away points will be altered, and in some cases may prevent the armature from operating, which might produce a dangerous condition.

It is not advisable to use oil on the armature pivots as it collects dust and is also likely to gum, thus interfering with the operation of the armature. Therefore it is desirable to have sufficient end-play in the bearings so that the armature will at all times move freely without lubrication of any kind.

105. Two of the curves shown in Fig. 52, indicate the pick-up** and drop-away current for relays wound to different resistances (1 to 16 ohms).

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*The air-gap which is about $\frac{1}{100}$ in., may be tested by a *thickness gauge* (a thin piece of sheet metal of a known thickness, a piece of brass $\frac{1}{100}$ in. thick frequently being used).

** *Minimum operating current.*

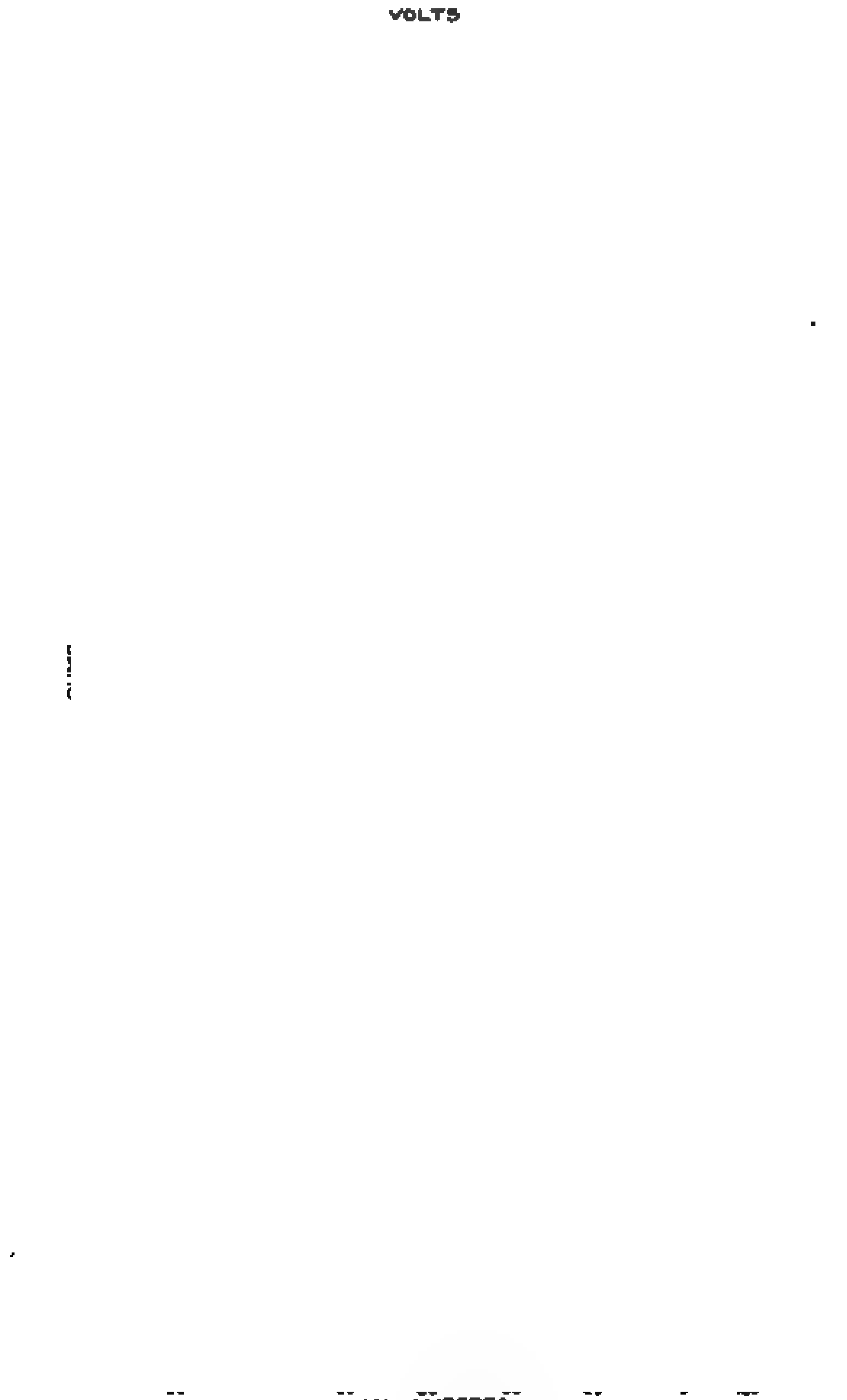


Fig. 52

The curve marked *normal operating current* indicates the value of the current required to insure the proper operation of the relay.. This value is increased from 2 to 25 per cent when relays are placed in service, to insure a satisfactory operating current under conditions which reduce the current flowing through the relay, such as leakage, or increased resistance in the circuit.

The curve marked *initial charge* indicates the value of the current which should be passed through the relay when testing for its drop-away point, as this point varies with the degree of magnetization of the cores. Although a relay when in service, is subjected to higher currents than the values given for the initial charge, nevertheless these values are considered great enough, as the drop-away point is not materially affected when a higher current is passed through the coils.

VOLTS

The voltage curves are self-explanatory.

106. The curves shown in Fig. 53, are plotted for relays varying from 100 to 1,000 ohms resistance.

The values indicated by these curves, also those indicated by the curves shown in Fig. 52, vary slightly for relays of different manufacture, and this in some instances may require consideration when testing for the pick-up and drop-away points.

107. The pick-up and drop-away points of the compound wound relays are as follows: The 16—16 ohm relay picks up at 45 mil-amps. and releases at 25 mil-amps.; the 24—24 ohm relay picks up at 40 mil-amps. and releases at 22 mil-amps.; the 12—

Fig. 53

150 and the 8—150 both pick up at about 67 mil-amps. and release at about 8 mil-amps.

108. The pick-up and releasing points of differential relays are not fixed as the movement of their armature is dependent upon the ratio which the current in one coil bears to that in the other.

109. **Testing**: In Fig. 54, is illustrated an adjustable resistance coil, which may be employed in testing relays for their pick-up and drop-away points.

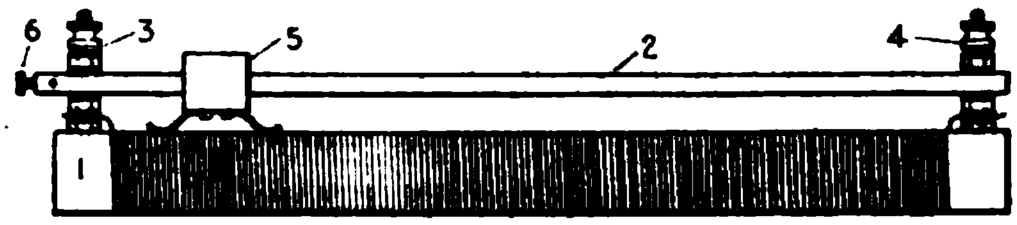


Fig. 54

It is composed of a brass tube 1 (about 1¼ in. diam. by 15 in. long), upon which one layer of ⅛ in. asbestos board is wrapped, upon this being wound No. 29 B. & S. G. insulated german silver wire.* Two coats of shellac are then applied to the wire and allowed to dry thoroughly, after which the outer surface of the wire is exposed by removing the insulation with a piece of emery cloth. A $\frac{5}{16}$ in. square brass rod 2, is supported by the binding posts 3 and 4, from which it is insulated. These posts which act as terminals for the coil, are attached to the tube but insulated from it. A contacting slide 5, which is mounted upon the brass rod and arranged so that it can be moved along it, makes contact with the rod and the coil. A binding screw 6 is attached to the rod as shown.

The wires of the circuit in which it is desired to have a variable resistance are connected to binding posts 3 and 6 or 4 and 6,** and the value of the resistance altered by moving contacting slide 5 to various positions on the rod.†

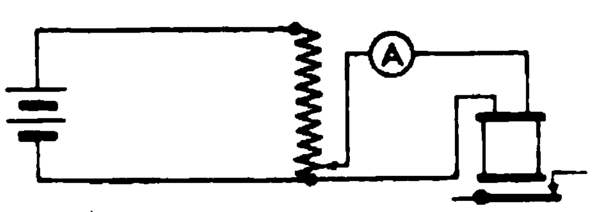


Fig. 55

110. An arrangement which may be employed when testing for the pick-up and drop-away points of relays, is shown in Fig. 55.

*Other high resistance wire may be used.
**All three posts may be used as shown in Fig. 55.
†This is a very useful instrument when conducting tests, as the resistance of a circuit can be varied by a fraction of an ohm.

Assuming that a 4-ohm neutral relay is to be tested we find from the curve in Fig. 52, that it should pick-up when 62 mil-amperes are passing through the coils, and drop-away when the current is reduced to 29 mil-amperes. We also note that the initial charge is 112 mil-amperes.

111. With the adjustable resistance connected as shown in Fig. 55, it is apparent that on account of the high resistance in series with the relay only a small current passes through it. The sliding contact is therefore gradually moved across the resistance, reducing its value and increasing the current flowing through the relay. When the relay attracts its armature the mil-ammeter should give a reading of about 62 mil-amperes. The current through the relay should now be increased to 112 mil-amperes (initial charge) and then reduced to 29 mil-amperes (drop-away point) at which value the armature should be released.

112. If the relay does not pick-up and drop-away with the proper amount of current passing through the coils, it should be adjusted as described in Arts. 101-103.

Relays should always be tested after repairing any of the parts which may affect the adjustment.

113. When testing a polarized relay for the pick-up and drop-away points of the neutral armature and the reversing point of the polarized armature, the connections should be arranged as shown in Fig. 56. The neutral armature should be tested with the pole-changing switch first in one position and then in the other.

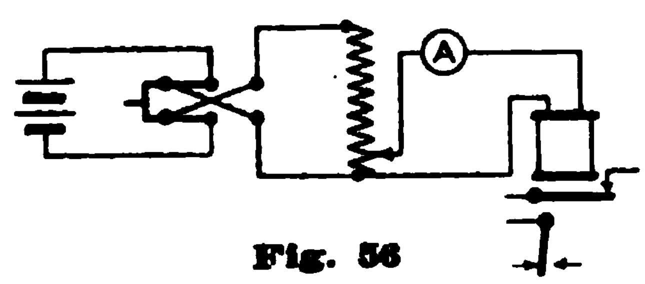


Fig. 56

After this test is completed the current through the relay should be reduced to about 50 per cent. of that required to attract the neutral armature, at which value the polarized armature should reverse upon the reversal of the pole-changing switch.

The polarized armature in some types of relays will reverse on less than 50 per cent. of the pick-up current.

If the polarized armature requires more than 50 per cent. of the pick-up current to cause it to reverse, the trouble may be traced to the binding of the movable parts, or to a weak permanent magnet.

114. Before being shipped from the factory relays are subjected to insulation break-down and residual magnetism tests. The former test is considered necessary on account of lightning discharges which are liable to interfere with these instruments, and the latter test, to avoid trouble from residual magnetism after the relays are installed.

115. The insulation break-down test usually consists of subjecting the insulation to a potential of from 3,000 to 5,000 volts, A. C. This test is made between the binding posts, and the base (when the latter is made of conducting material), and between the core and the first layer of the windings.

116. The test for residual magnetism consists of subjecting the coils to a voltage considerably higher than they receive when in service. For instance, relays wound to a resistance of less than 100 ohms are tested with a pressure of from 25 to 40 volts, D. C., and those wound to resistances varying from 100 to 1,000 ohms, to a pressure of from 100 to 150 volts.

If under this test the armature does not release within 5 sec. after the testing circuit is opened, it is usually an indication of the presence of residual magnetism. The cores of relays subject to this trouble should be replaced, as the armature remaining picked-up when it should be released, is likely to cause dangerous conditions.

When slow releasing relays are subjected to these tests the armature should generally release in from 6 to 8 sec., but in some instances, will run as high as 15 sec.

117. The resistance between the contact points of a relay varies considerably, usually increasing from about .03 ohm, when the relay is installed, to about .12 ohm after it has been in service for some time.

If it appears that trouble is being experienced from this source, the resistance between the contact points may be tested by the use of a Wheatstone bridge or if such an instrument is not available, by the use of a low reading voltmeter and a mil-ammeter arranged as shown in Fig. 57,* the resistance being calculated by Ohm's law.**

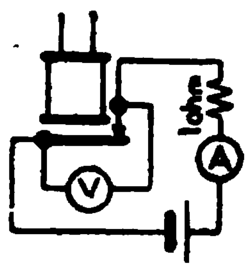


Fig. 57

If it is found that considerable resistance has developed between the contact points, they may be cleaned by passing a piece of fine emery cloth or sand paper between them. In some instances fine files† (Swiss cut) are sometimes employed for this purpose. Considerable care must be exercised, to avoid grooving or sloping the contact surfaces, or removing more material than necessary.

INSTALLATION AND MAINTENANCE

118. Installation: Relays should not be placed too close to steam pipes, or beneath water pipes as water is liable to drop from them, nor at points where they would be subjected to storage battery gases, or where they would be influenced by external magnetic forces, such as in the vicinity of electrical machinery.

119. Where relays are so located that they are subjected to considerable vibration, as for instance on some elevated railroad structures, it is advisable to set them upon felt about 1 in. thick. In some cases where this precaution has not been taken, the vibration caused arcing between the contact points resulting in damaging these points by burning and in some cases opening the controlled circuits momentarily.

120. Jumper wires‡ employed to connect two or more binding posts together, are usually made of No. 14 rubber-covered or weather-proof solid copper wire. Office wire, lamp cord, and rubber-covered flexible wire are also used for this purpose.

*The 1-ohm resistance is desirable to prevent possible injury to the mil-ammeter.
See **Magnetism and Electricity.
†Known as jewelers' files.
‡See Art. 88.

121. As in some cases, the resistance which frequently develops between contact points, interferes with the proper operation of the controlled circuit, it is often carried through two or more sets of contacts connected in multiple. This is also so arranged in order to insure the proper operation of the controlled circuit in case one of the contacts fails.

In some types of polarized relays, on account of the pressure exerted by the polarized armature on its contacts being weaker than that exerted upon the neutral contacts, the resistance between the polarized contact points generally increases more rapidly than between the neutral contact points.

122. Maintenance: As the function of relays is generally very important and as they are delicate instruments, they must be inspected frequently. The condition of the contacts and insulating bushings, etc., should be noted and the binding posts should not be allowed to become loose. When inspecting, care should be exercised to avoid bending the wires leading to the coils, as they are liable to break if handled carelessly.

An instrument brush* is a convenient tool for cleaning or dusting relays.

Salts due to corrosion (Art. 17) should not be allowed to collect as they insert resistance into the circuit, and in rare cases, where the salt creeps onto the contacting surfaces, may cause the armature to remain up when the relay is de-energized.

123. If water collects upon the operating parts of a relay, it should be cleaned immediately or if possible removed from service, especially if subjected to cold weather as the contact points are liable to freeze together, and thus may produce a dangerous condition. The manner in which the water collected should be ascertained and if possible the trouble remedied.

124. The operation of a relay which is in service, may be tested by placing a jumper across the binding posts leading to the coils.** This method cannot be employed in all instances,

*See **Tools.**

**Before making this test, its effect upon the apparatus controlled by the relay or upon any instrument connected in multiple with it, should be considered.

as for example where the relay is supplied with current from a storage battery, in which case the shunting of the relay would probably cause an excessive flow of current. This will indicate whether the relay will release under such conditions, and also, when the shunt is removed, whether it will pick-up.

125. It is the general practice to inspect relays after thunder storms, with a view to insuring that the contact points have not been damaged, possibly being fused together, by lightning discharges. Such discharges are also apt to break down insulation, especially between adjacent windings, thus reducing the resistance of the coil, or between the windings and the cores, this being caused by the carbonizing of the insulation or the flowing of metal as the result of an arc. In some cases lightning will entirely destroy a relay.

If it is thought that there is defective insulation, it may be tested with a magneto, or other suitable instruments.

R. S. A. SPECIFICATIONS

126. Type: All relays must be of the enclosed type with all working parts enclosed in a transparent case.

All relays shall be sufficiently water-tight to stand a water immersion test of at least ten (10) minutes.

Material and Workmanship: Magnet cores and armatures shall be made of the best quality of soft annealed iron, and all other materials used in the construction of relays shall be of good quality, free from defects; workmanship and finish shall be satisfactory to purchaser.

Armature Supports: Armature supports must be securely mounted on the magnet cores, or the armature supports and cores may be mounted on the same piece of metal, in such manner that the same relative position of armature and core faces will always be maintained.

Trunnions of armature bearings shall be hard drawn german silver, shall be cylindrical and at least one-sixteenth (1-16") inch in diameter.

Trunnion screws must fit tightly in their supports and be provided with jamb nuts or other suitable fastenings.

Armature: Springs, adjustable stops or other means of adjusting armatures vertically will not be permitted.

A minimum air gap of one-sixty-fourth (1-64") inch between armature and magnet cores shall be insured by bone or brass pins driven in end of cores or in armature.

Stop pins must be driven firmly to the bottom of the holes drilled for their reception and secured by cupping.

Contact Springs: Contact springs or fingers shall be mounted rigidly on the armature not less than three-eights (⅜") inch from nearest face of same and shall be sufficiently heavy to retain any adjustment they are given.

Contact Points: All contact points shall make sliding contact.

Stationary front contact points of track relays shall be of non-fusible materials and back contact points shall be of platinum.

A closed contact shall not have more than 0.13 ohm resistance.

All contacts shall have a minimum opening of one-sixteenth (1-16") inch.

Magnet Coils: All magnet coils must be convenient of application to core; all insulation shall be applied before coils are assembled on cores and when assembled they must be securely held to prevent vibration.

The wire for magnet coils shall be soft drawn copper covered with a good quality of silk or cotton braid or equally good insulation and of proper size to give resistance specified.

The ends of connecting magnets shall be soldered, non-corrosive flux being used, or may be joined with substantial accurate binding posts provided with lock nut.

Terminal wires of magnet coils shall not be less than number twenty (20) B. & S. gauge.

Magnet coils shall be encased to prevent mechanical injury to wire.

Binding Posts: Binding posts shall be of brass of such construction that they will not turn in the base or frame on which they are carried. The stud carrying thumb screws for fastening wires shall not be smaller than 10-32.

Insulation: An air gap of not less than three-eighths (⅜) of an inch, or approved insulation equivalent thereto shall be provided between any part of the relay carrying current and any other part thereof. Parts so insulated shall withstand a test with an alternating current of three thousand (3,000) volts for one minute.

Resistance: All track relays shall be of four (4) ohms resistance, unless otherwise specified.

Adjustment of Relays. Track 4 ohm: Four (4) ohm track relays shall be adjusted to release at not less than thirty (30) mil-amperes after an initial charge of one hundred and ten (110) mil-amperes has been given for one minute.

After relay has been adjusted to release as specified, the current through coils shall be reversed when armature shall pick up at not more than sixty-five (65) mil-amperes.

16 ohm: Sixteen (16) ohm track relays shall be adjusted to release at not less than fourteen (14) mil-amperes after an initial charge of fifty-five (55) mil-amperes has been given for one minute.

After relay has been adjusted to release as specified, the current through coils shall be reversed, when armature shall pick up at not more than thirty-six (36) mil-amperes.

All Track Relays: If after a relay has been adjusted as specified, the front contact points are adjusted so they do not make contact when relay is energized, the initial charge is applied and gradually reduced to forty (40) per cent. of normal release current, the armature shall release.

Adjustment of Relays-Line Relays: Relays shall be adjusted so armatures will pick up and give good sliding contact as follows:

One hundred (100) ohms at not more than 1.7 volts.

Two hundred and fifty (250) ohms at not more than 2.6 volts.

Five hundred (500) ohms at not more than 3.6 volts.

Seven hundred and fifty (750) ohms at not more than 4.4 volts.

One thousand (1,000) ohms at not more than 5.0 volts.

After being adjusted as specified the voltage required to pick up the armature shall be increased one hundred (100) per cent. and then gradually decreased by means of variable resistance, and armature shall release when voltage is reduced to forty (40) per cent. of the voltage required to pick up same.

All Line Relays: If after relay has been adjusted as specified the front contact points are adjusted so they do not make contact when relay is energized, and the voltage required to pick up armature increased one hundred (100) per cent. is applied and gradually reduced, relay shall release at not less than sixteen (16) per cent. of the pick-up voltage.

Residual Magnetism: Before adjusting, all relays of less than one hundred (100) ohms resistance must be subjected to a momentary e. m. f. of not less than forty (40) volts, and all relays of more than one hundred (100) ohms resistance must be subjected to a momentary e. m. f. of not less than one hundred (100) volts nor over five hundred (500) volts.

Sealing and Marking: All relays must be sealed with the manufacturer's seal, and all adjustments marked plainly in the sealed portion of the relay.

Test after Assembling: All tests are to be repeated after relay has been assembled and sealed.

EXAMINATION QUESTIONS

(1) (*a*) What is a neutral relay? (*b*) What is a polarized relay?

(2) Why is it necessary, with the relay shown in Fig. 1, to insulate the binding posts from the base?

(3) How could you raise the pick-up point of the relay illustrated in Fig. 1?

(4) (*a*) When is a relay said to be closed? (*b*) When is it said to be open?

(5) Would a 4-ohm neutral relay, which is properly adjusted, pick-up with 50 mil-amperes flowing through its coils?

(6) Explain the purpose of hooks 8, in Fig. 20.

(7) What causes the polarized armature of a polarized relay, to reverse?

(8) Why do the polarized contacts, of the relay illustrated in Fig. 43, still make good contact when the relay is de-energized?

(9) Why is it desirable to provide better insulation in relay magnets than in the ordinary types of electromagnets?

(10) What do you understand the terms "pick-up point" and "drop-away point" to mean?

(11) Explain how you would test a 9-ohm relay for its pick-up and drop-away points?

(12) Why are circuits controlled by relays, sometimes carried through two contacts in multiple?

(13) Give a reason why it is inadvisable, in some cases, to test a relay by shunting it with a jumper.

(14) Why should relays be inspected after thunder storms?

(15) From the curves shown in Fig. 52, find the pick-up points in amperes and volts for a 5-ohm relay.

(16) From the curves shown in Fig. 53, ascertain the pick-up point in amperes and volts for a 500-ohm relay.

(17) If, when making the test shown in Fig. 57, the ammeter gives a reading of 0.8 amp. and the voltmeter a reading of 0.2 volt, what would be the resistnce of the contact?

(18) When testing a 12-ohm relay in the manner shown in Fig. 55, what reading should the meter give when the armature drops away, assuming that the relay is properly adjusted?

(19) Why is it undesirable to locate relays where they would be subjected to considerable vibration?

(20) Why is the insulation of relays given a break-down test?

D. C. TRACK CIRCUITS

1. Definition: As used in railway signaling, the term *track circuit* signifies an electric circuit, in which the *running rails* of a track are used as conductors; the arrangement being such that the presence of the *wheels* of a car or train on the conducting rails is indicated by their effect upon the flow of current and consequently upon an instrument, usually a relay, which forms a part of the circuit.

A track circuit arrangement commonly used is shown in Fig. 1. Insulating devices 1 known as *insulated rail joints* are

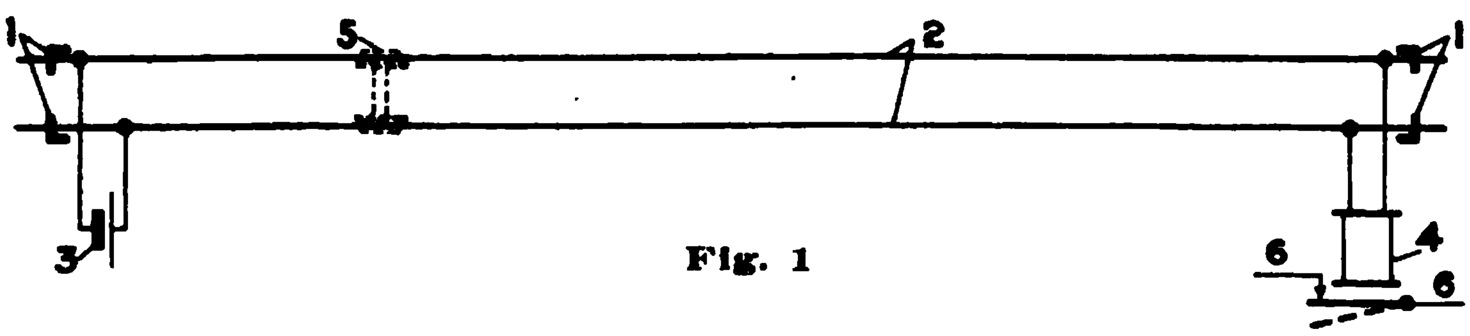


Fig. 1

placed in the *running rails* 2 where the circuit is to end. When there is no train on the conducting rails 2 the *relay* 4 is energized by current from the *battery* 3, but if the track is occupied by *wheels* 5, as shown by dotted lines, the greater part of the current passes through them, and is therefore *shunted out* of the relay, the armature of which assumes the dotted position, thus breaking the *circuit* 6, which controls signal apparatus.

MATERIALS OF CONSTRUCTION

RAIL BONDS

2. As the running rails of the track are used for conductors it is necessary to have the rail-lengths, between the insulated joints, *electrically connected* to form a continuous conductor. Although the ordinary splice-bars used in joining rails are made of conducting materials, it has been found that they can-

not be depended upon to carry the current satisfactorily. This is due, first to the fact that the bolts often become somewhat loosened and do not hold the bars tightly against the rails, and second to the rust which collects on the bars and rails thus preventing good electrical contact. It is therefore necessary to provide means to insure good electrical conductivity at the rail joints. To secure this, wire conductors known as **rail bonds*** are employed.

3. Types of Rail Bonds: The types commonly used for signal purposes are made of the following sizes and kinds of wires:

No. 8, B. W. G., galvanized iron.
No. 9, B. W. G., galvanized iron.
No. 6, B. & S. G., soft-drawn copper.
No. 6, B. & S. G., copper clad steel.

These wires are large enough to fulfil the mechanical requirements and to conduct the required amount of current.

4. Iron Bond Wire: Iron bond wire should be of the quality known as Ex. B. B.** It should be *pliable*, *tenacious*, and *well galvanized*. Pliability is necessary in order that the wire may be bent into the desired shape when being applied to the joint. Tenacity is necessary so that the bond will not break when bent or twisted by careless trackmen and others working about the rails. Galvanizing is necessary to prevent oxidization, which would quickly consume the wire.

5. Copper Bond Wire: A good quality of soft drawn copper wire fulfils the requirements for pliability and tenacity. It is desirable in some cases, to have the wire tinned, as this will tend to protect it from chemical action.

6. Copper Clad Steel Bond Wire: The grade known as "MD", annealed, is ordinarily used for bonding. In some cases a coating of tin is desirable to protect it from chemical action, as in the case of copper bonds.

*Also called *bonds*, *track wires*.
See **Wires and Cables.

7. Iron and copper bond-wires are supplied in lengths to correspond with the style of joint at which they are to be used, or the wire may be procured in coils and cut to any desired length. The former is considered the better practice for regular work, because the wires, being straight, and of uniform length generally produce a better appearance. They are also installed more economically. When bonding frogs and switches, it is convenient to be able to cut the wire into various lengths as circumstances require. Therefore a supply of both should be available.

8. Connection of Bond Wire to the Rail: There are two general methods of attaching bond wires to the rails. First, by means of plugs,* and second, by means of channel pins or bonding tubes.

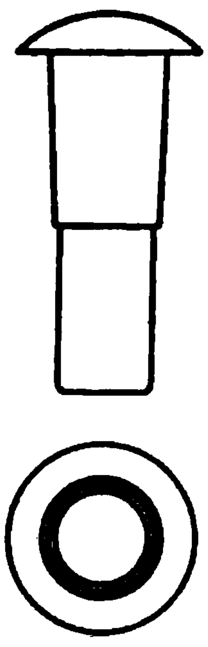


Fig. 2

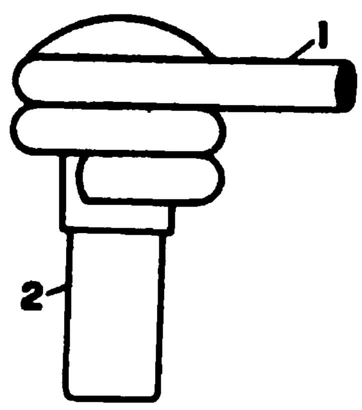


Fig. 3

A full size view of a *bond wire plug* is shown in Fig. 2. This should be made of a good quality of annealed rivet iron. The *bond wire* 1 is soldered to the *plug* 2 as shown in Fig. 3, and the entire joint and plug tinned. This is generally done at the factory where conditions are such, that it can be handled economically.

The bond wire plug is being superseded by the *channel pin* and *bonding tube*.

Full size views of two ordinary types of *channel pins*, are shown in Fig. 4. These are made from iron or mild steel and are either copper plated or tinned.

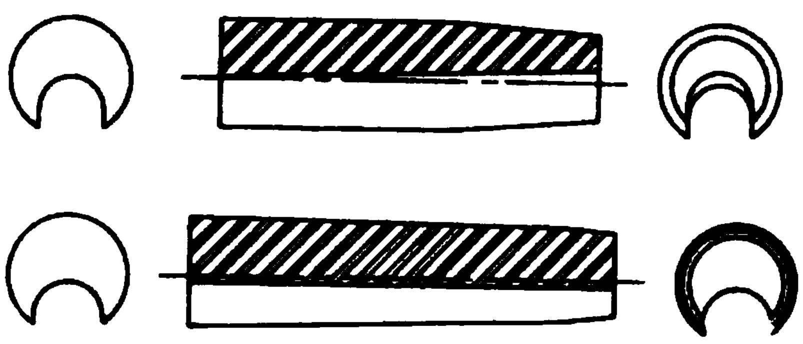


Fig. 4

A *bonding tube* is illustrated in Fig. 5. It is made of the same kind of material and finished the same as the channel pin.

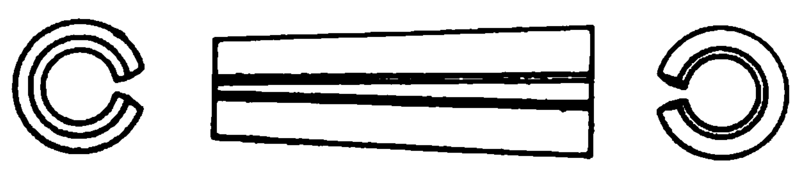


Fig. 5

*Also called *rivets*.

9. The relation of the *bond wire* 1, to the rail joint is shown in Fig. 6. These wires usually vary in length from 40 in. to

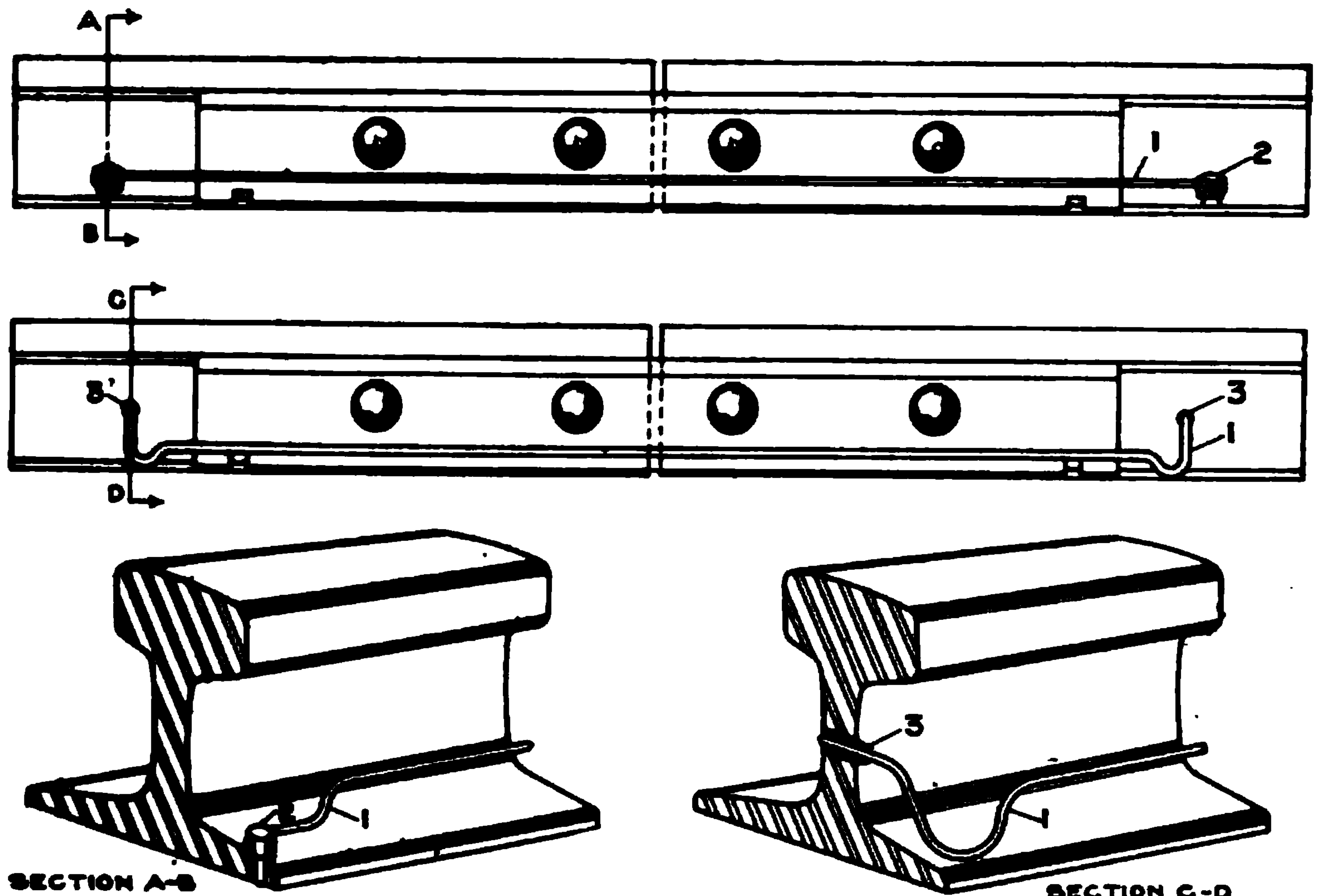


Fig. 6

60 in., the size being governed by the length of the splice plates. This figure also shows the application of the *bond wire plug* 2, and *channel pin* or *bonding tube* 3.

10. On railroads where the traffic is propelled by electricity and the track is also used as a return path for the propulsion current larger types of rail bonds, than those described, are necessary.

11. When bonding at frogs, switches and derails it is frequently necessary to fasten the bond wires to the ties to keep them in place. Galvanized iron *staples* 2 in. long are used for this purpose.

INSULATED RAIL JOINTS

12. In connection with track circuits it is necessary to *electrically separate* the ends of two adjacent rails. This is accomplished by the **insulated rail joint** which is applied in place of the regular splice bars.

13. The simplest type of insulated rail joint now in use is shown in Fig. 7. From its construction it derives the name of **splice-woods.**

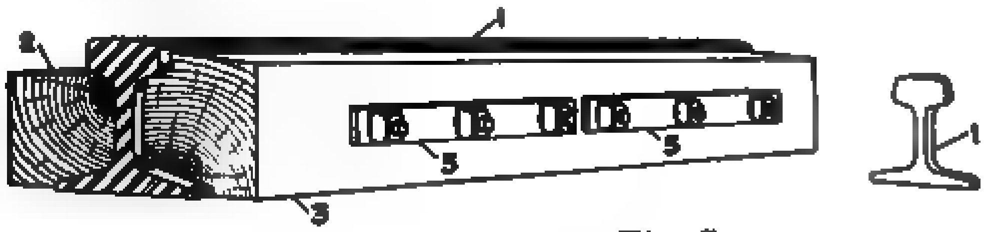


Fig. 7

A piece of *vulcanized fiber* 1, about ¼ in. thick, known as an *end post,* is placed between the ends of the rails, to prevent electrical contact between them. *Hard wood blocks* 2 and 3 known, respectively, as *inside* and *outside woods,* take the place of the ordinary iron or steel splice bars, white oak, hickory and yellow pine, sometimes coated with oil, or asphaltum paint, being used for this purpose.. These blocks are strengthened by *reinforcing bars* 5, and are held in position by *bolts* and *lock washers* 4. There is no metallic connection between the two rail lengths as the fiber and wood are insulators, consequently current is *prevented* from passing through the joint.

The splice-woods are not as rigid as the iron or steel bars which are used in the construction of other types of insulated joints.

The tendency of the wood to shrink and swell is liable to loosen the bolts which thus require considerable attention.

14. Another type of insulated rail joint is shown in Fig. 8. About ⅛ in. is planed from the top and bottom of the *splice bars* 1 and the space thus provided is occupied by *fiber plates** 2, placed between the bars and rail. *Fiber bushings*** 3 are placed around the *bolts* 4 in the rail, the holes being reamed to contain them. In this manner the bars and bolts are kept

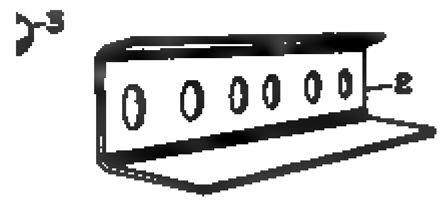


Fig. 8

*Also called *fiber angles* and *fiber sheets.*

**Also called *fiber thimbles.*

from touching the rail. The fiber end post is used in the same manner as with the "splice-woods".

15. A type of insulated rail joint somewhat similar to that shown in Fig. 8 is illustrated in Fig. 9. The *bolts* 6 are allowed to come into contact with the rail but are insulated from the *splice bars* 1 by *bushings* 3 and *washers* 4. The *fiber plates* 2 are similar to those shown in Fig. 8. The holes in the bars are made large enough to accommodate the bushings, and the fiber washers are protected by *iron washers* 5 placed under the boltheads and nuts as shown.

Fig. 9

16. A modified form of the "splice-woods" is shown in Fig. 10. This joint is known as the **Weber insulated rail joint** and

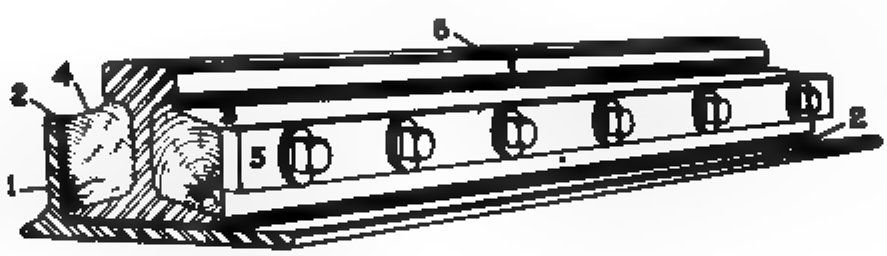


Fig. 10

is constructed as follows: The *metal shoe angle** 1 is a rolled steel plate which supports the rail ends from underneath and reinforces the *outside wood filler* 4. The *fiber shoe angle*** 2 insulates the rail from the metal shoe angle and is held in place by the *bolts* 10 which pass through holes in the vertical portion of the fiber. The *reinforcing bar*† 5 is a piece of rolled steel which reinforces the *inside wood filler* 3. The bolts are insulated from the metal shoe angle and from the reinforcing bar by *fiber washers* 8 and *bushings*‡ 7, protected by an *iron washer* 9 as in Fig. 9. The *fiber end post* 6 is the same as shown in Fig. 7, *two* ordinarily

*Also called *chair* and *angle bar*.
**Also called *fiber mat, fiber plate, fiber sole plate* and *angle insulator*.
†Also called a *strap*.
‡A bushing and washer combined is sometimes called a *fiber bolt bushing*.

being used in each joint. The *wood fillers* 3 and 4, shown in Fig. 10, are interchangeable but in some cases, the outside filler 4 is constructed as shown by the dotted line and when so constructed they are not interchangeable.

As may readily be seen the additional stiffness of this joint is derived from the support given to the rail and wood fillers by the metal shoe angle and continuous reinforcing bar.

17. The **Atlas insulated rail joint** shown in Fig. 11 is a modification of the joint shown in Fig. 8. The splice bars are

Fig. 11

extended and turned under the rail, two additional bolts being used as shown. The *bottom fiber plate* insulates this part of the joint from the under side of the rail, a row of holes along the center of this plate providing drainage and ventilation. The fiber bushings in the rail are protected by *steel ferrules.* Vertical and diagonal ribs are cast on the outside of the splice bars and horizontal and diagonal ribs on the inside.

18. The **Keystone insulated rail joint** is illustrated in Fig. 12. The *metal fillers,* A, which are a feature of this joint, provide an increased area of fiber to withstand the

Fig. 12

shock from wheels passing over the joint. These fillers and the *angle bars*, B, are of rolled steel.

As this joint does not extend below the base of the rail, no dapping* or lowering of the ties is necessary. This feature is advantageous on unballasted bridges and structures.

19. The **Mock insulated rail joint** is shown in Fig. 13. The distinctive feature of this joint is the *auxiliary rail*, which bridges the gap between the two service rails and carries the wheel treads over the rail ends.

Fig. 13

20. The *Weber* insulated rail joint adapted to use with guard rails, is illustrated in Fig. 14. The *Keystone* similarly arranged

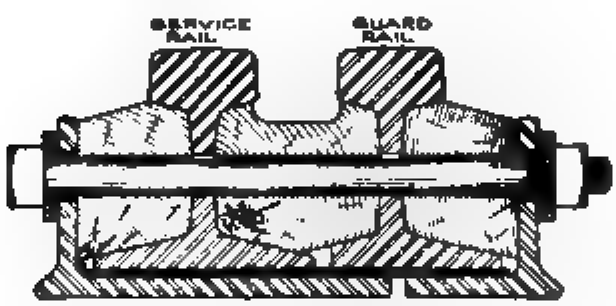


Fig. 14

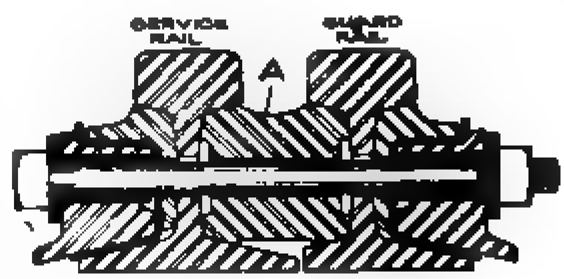


Fig. 15

is shown in Fig. 15. It will be noted that the *filler* A is shown as metal although wood fillers are sometimes used. Metal fillers which are of cast iron or cast steel, are made in two parts to prevent current from passing through the joint.

21. Fig. 16 illustrates the adaptation of the *Weber* for use with frogs having guard and tread rails.

TREAD RAIL SERVICE RAIL GUARD RAIL

Fig. 16

*Cutting

22. It should be understood that insulated rail joints of the types illustrated cannot be considered perfect insulation. However, the voltage used for track circuits being low, (between 1 and 10 volts) sufficient insulation resistance is secured to prevent the leakage of enough current to affect the operation of the instruments forming part of the track circuit or to affect adjoining track circuits.

SWITCH AND PIPE LINE INSULATION

23. In the operation of a track circuit it is necessary, except as explained hereafter, that there be no *electrical connection* from one running rail to the other. This would occur if a switch were located within the limits of a track circuit, unless some arrangement is made to prevent it. This is illustrated

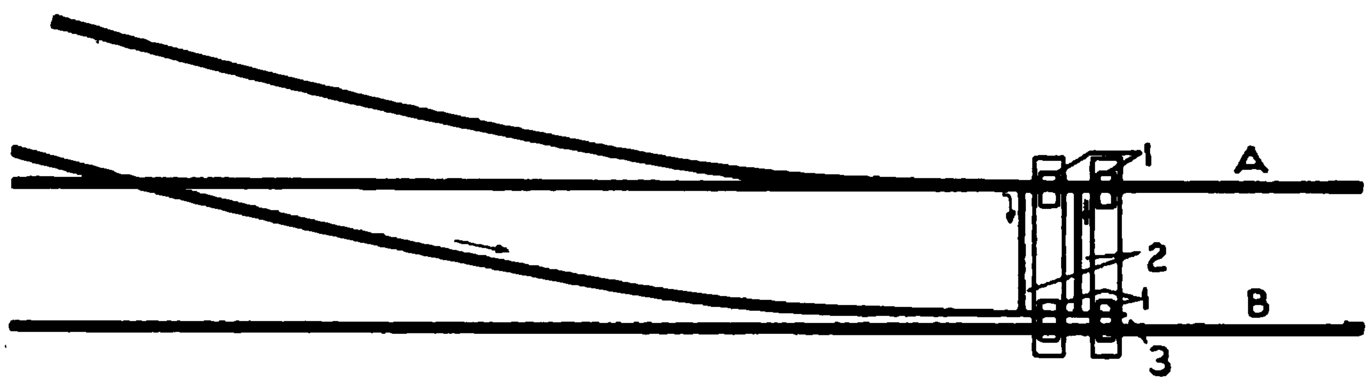


Fig. 17

by the switch layout shown in Fig. 17 which indicates, by the arrows, several possible paths through the *slide plates* 1, *switch rods* 2 and *cross rail*, for the current to pass from rail A to rail B. Some means must therefore be provided to interrupt these paths.

24. One method of accomplishing this is shown in Fig. 18. An *insulated rail joint* 1, is placed in the cross rail and

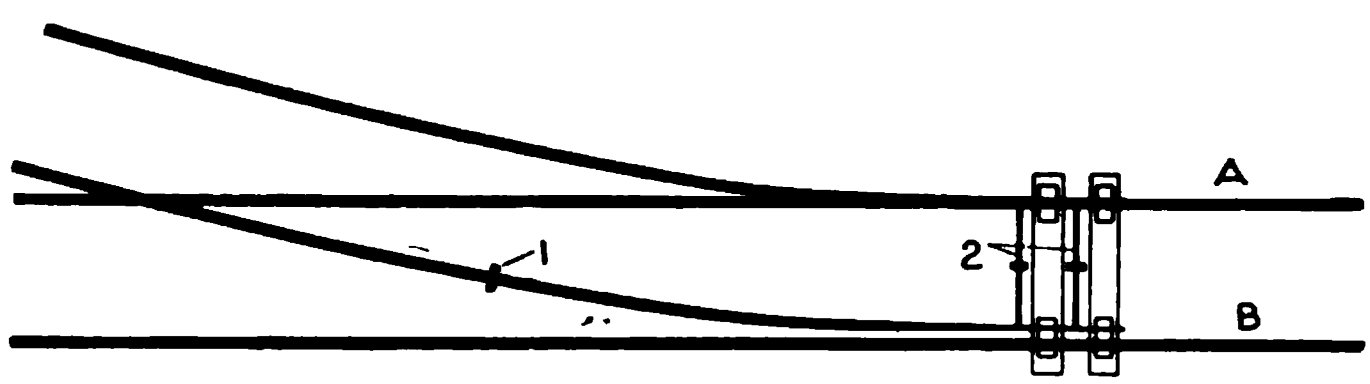


Fig. 18

insulated switch rods 2, are used, therefore the current cannot pass from rail A to rail B.

25. Switch Rod Insulation: Switch rods may be insulated in a number of ways. It may be done where the rod is attached to the switch lugs as shown in Fig. 19, by the use of a *fiber bushing* 1 and *fiber washers* 2. This insulating is arranged at *one* end only, of the switch rod.

Fig. 19

The switch rod must not be allowed to touch the stock rail, and to avoid this either the switch rod is offset as shown at A, or a switch lug with more *drop* is used. As this arrangement permits the switch points to rise, some engineers consider it undesirable on account of possible interference with snow plows.

If the bushing becomes softened the switch point may not properly close up against the stock rail.

This method, although easily applied and permissable when other means are not available, is not considered very good practice.

26. The type of switch rod insulation shown in Fig. 20 has given satisfactory results. The *switch rod* 1 is in two parts

Fig. 20

being separated about one-half inch. These are held firmly together by iron or steel *splice plates** 2 secured with *bolts* 3, the joint being so insulated with *fiber plates* 4 and *bushings* 5 that current cannot pass from one part of the switch rod to the other. The nuts are locked by lock washers, cotters or other devices.

*Also called *straps* and *fish plates*.

27. Occasionally trouble has been experienced with the switch rod insulation shown in Fig. 20 on account of a conductor, such as a spike, nail or a piece of wire, getting into the space between the two parts of the switch rod, thus making

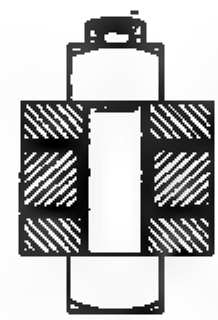


Fig. 21

an electrical connection between them. In order to overcome this fiber is placed as shown in Fig 21.

It is common practice to use either four or six bolt splice plate joints.

A point to be considered in regard to the insulated switch rods shown in Figs. 20-21, is the length of the bushings. Defective insulation has occasionally resulted from a conductor, such as chips of steel made when drilling the rod, *bridging* the end of the bushings as at point A, Fig. 20. This is remedied by extending the bushings as shown in Fig. 21.

28. A modification of the switch rod insulation shown in Fig. 21 is illustrated in Fig. 22. The feature of this type is

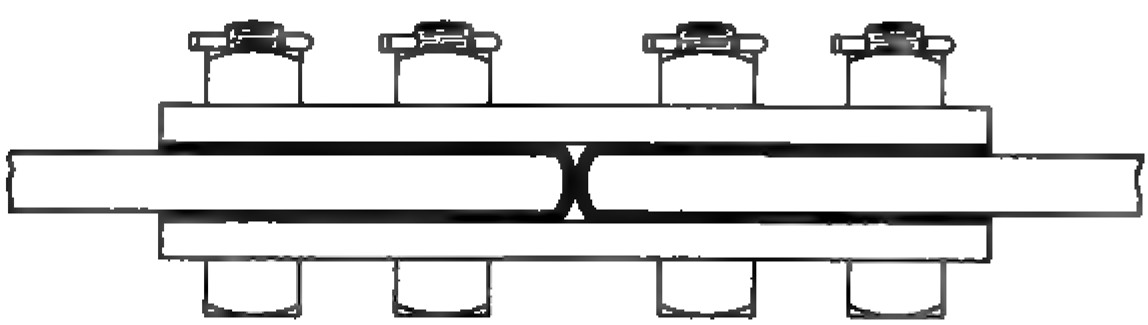


Fig. 22

the use of *two* fiber plates instead of four. This is a good arrangement for the splice plate joint.

29. Another form of switch rod insulation shown in Fig. 23, is known as the *lap joint.* Sometimes more than two

bolts are used. An alternative arrangement of bolt insulation is indicated by section A.

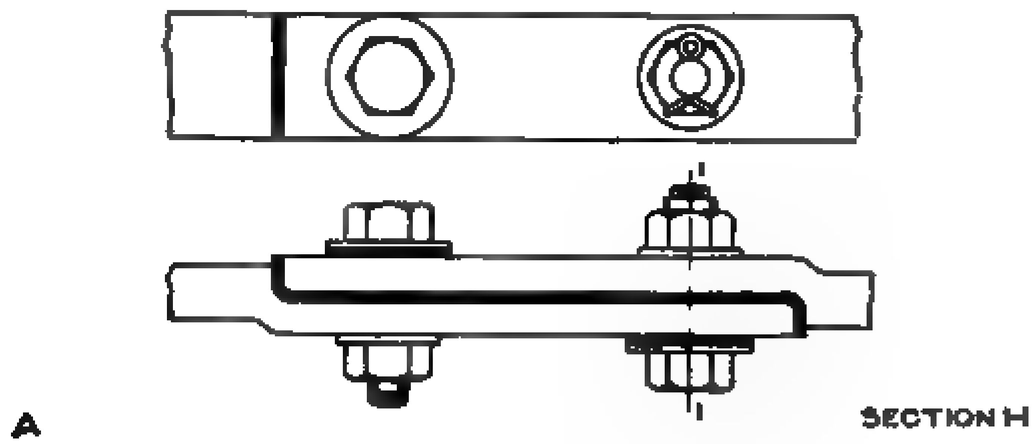


Fig. 23

30. In Figs. 24-25 are illustrated two methods of insulating switch rods, known as ***butt joints.*** The former is manufactured ready for welding into the *switch rod* which is shown by dotted lines. In the latter the *intermediate block* A is made of cast steel. The fiber under the bolt heads is protected by wrought iron plates separated at the center of the joint.

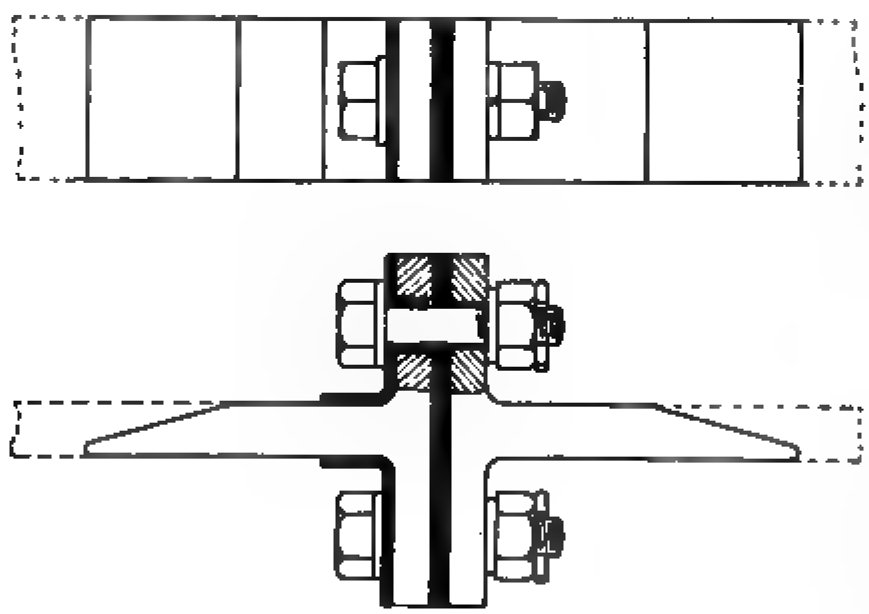


Fig. 24

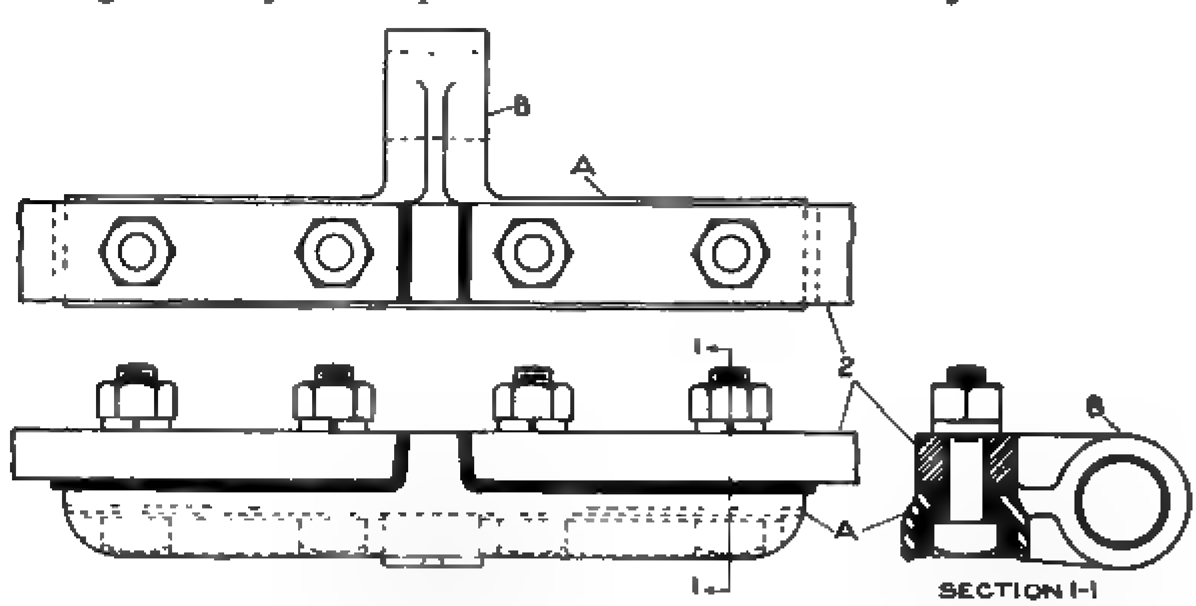


Fig. 25

31. In many cases it is necessary to interrupt a path, through the *throw rod* 1, Fig. 26, by which current might flow

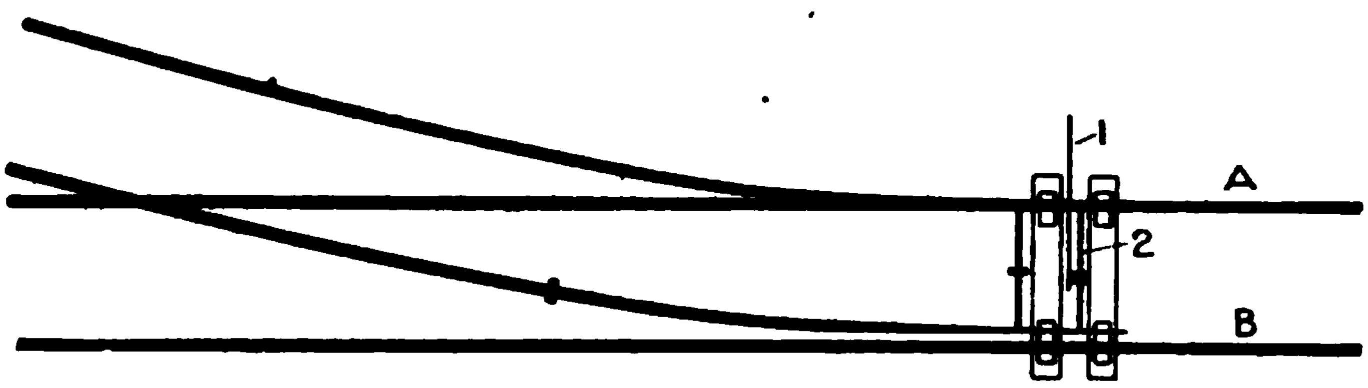


Fig. 26

between the rails and the operating connections. A method of accomplishing this is shown in Fig. 25. A lug B is cast on one side of the intermediate block A, to which is attached the throw rod. As this block is insulated from both parts of the *switch rod* 2, current cannot pass between the rails and the throw rod.

32. Another method of accomplishing this is to insert an insulated joint in the throw rod. The types shown in Figs. 20-24 are available for this purpose.

33. In some cases it is necessary to insulate the throw rod from one rail only. In Fig. 27 a *lap joint* is used

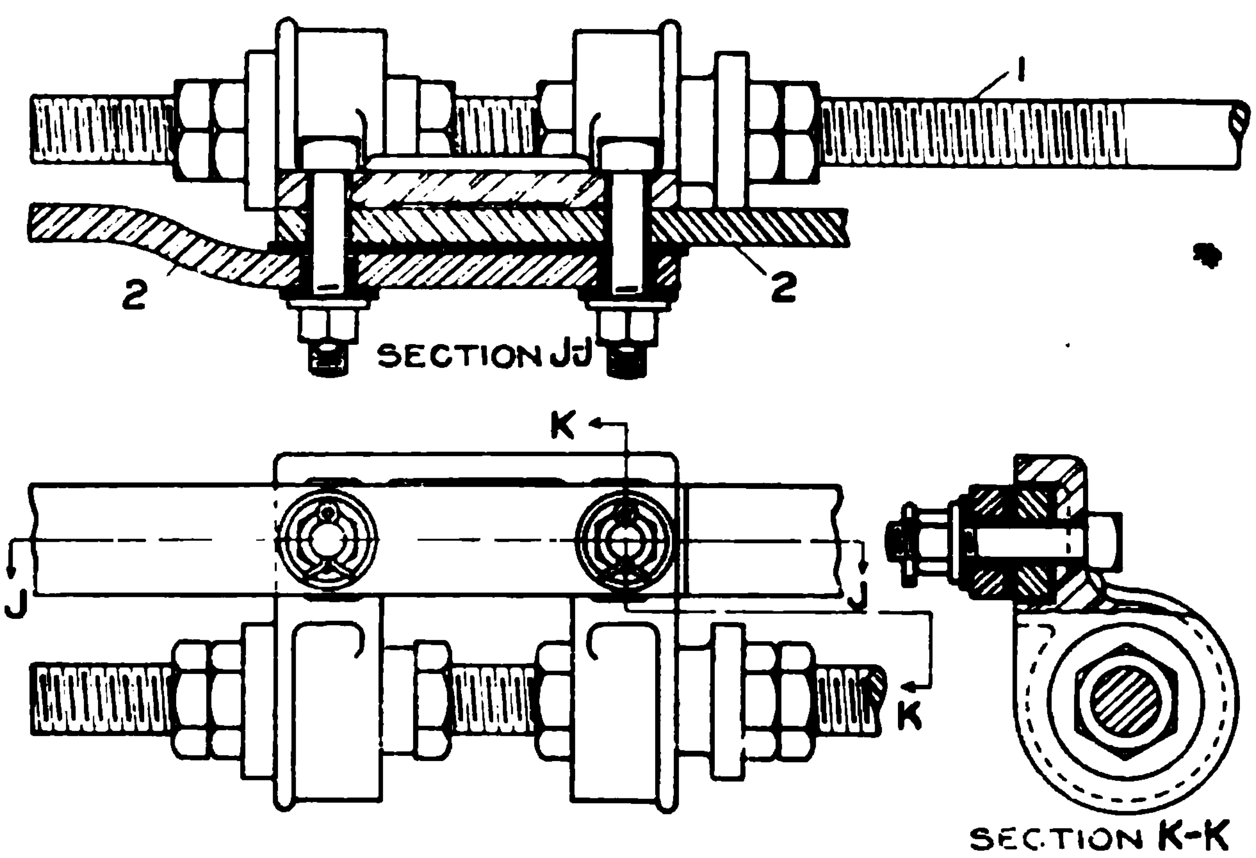


Fig. 27

which insulates the throw rod from rail B, Fig. 26, but not from rail A.

34. Insulated Front and Lock Rods: When switches are interlocked it is customary to apply connections to the

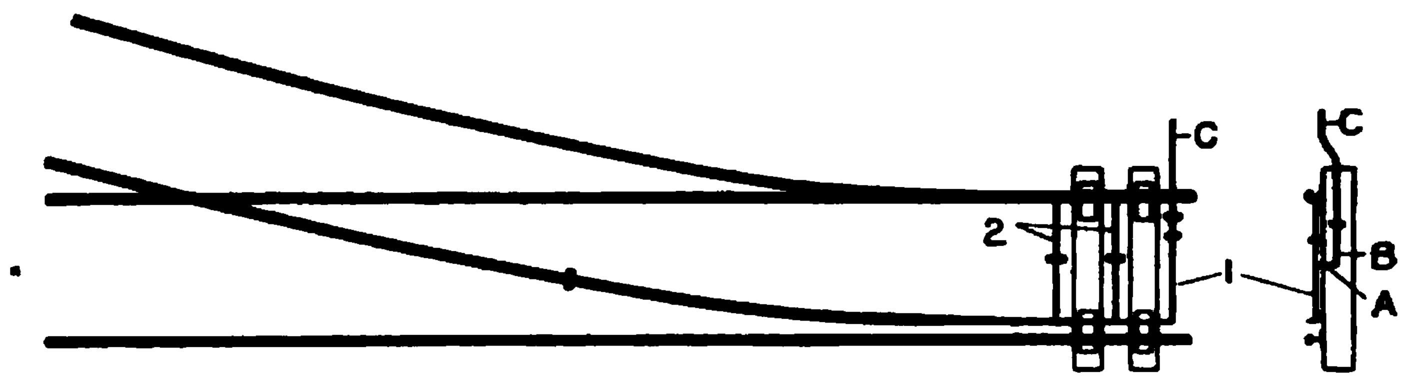


Fig. 28

switch, known as *front* and *lock rods.* As the *front rod* 1, Fig. 28, is connected to the switch points in a manner similar to the *switch rods,* 2, it has to be insulated. An *insulated front rod* is shown in Fig. 29.

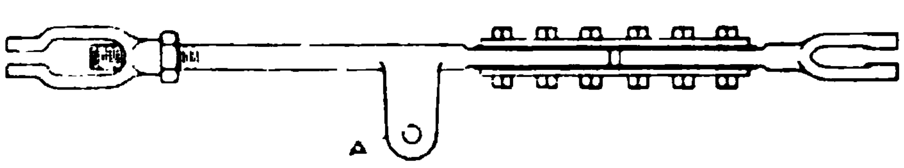


Fig. 29

An *insulated front rod* for use with a single point derail is shown in Fig. 30.

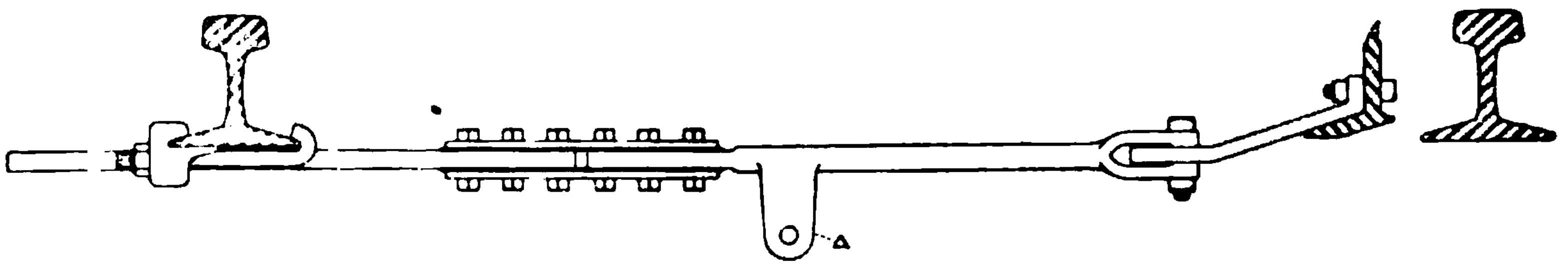


Fig. 30

35. As *lock rods,* an illustration of which in shown in Fig. 31, are attached by means of jaw B, to lug A on front rods.

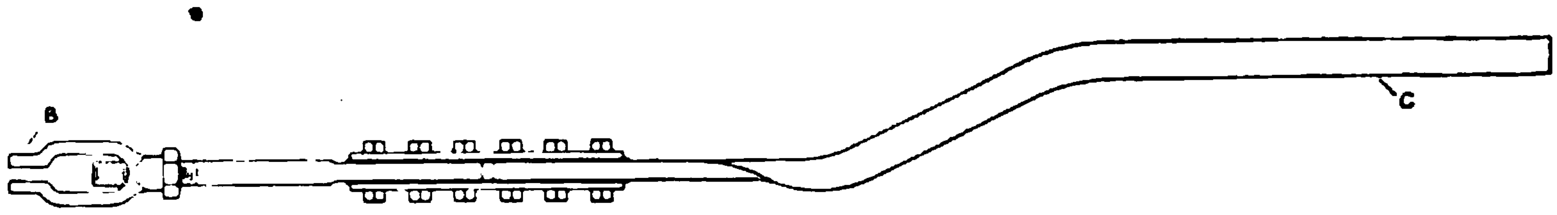


Fig. 31

Figs. 28-30, it is frequently necessary to insulate the lock rods as shown, to prevent the flow of current between the rails and operating connections, with which blade C comes into contact.

36. Wedge Blocks: Reference to Fig. 17 will show that the contact between the *switch point* 3 and the *slide plates* 1 forms a part of all paths by which the current can pass from rail A to rail B. If the switch point is insulated from these

plates all the paths will be interrupted and electrical connection between the rails broken. This insulation may be provided

Fig. 32

in the form of an air gap, the switch point being raised from the slide plates by one or more *wedge blocks* 2 as shown in Fig. 32.

Various designs of these blocks are illustrated in Fig. 33.

When the switch is in the reversed position to that shown in Fig 32, the *switch point* 3 moves down the incline of the *wedge* 2 into contact with the *slide plate* 1, thus completing a possible path between the rails. In all cases where wedge blocks are used it is desirable to have the rails thus electrically connected when the switch is reversed and therefore this feature does not interfere with the proper operation of the track circuit When it is desired to have the rails electrically separated in both positions of the switch, wedge blocks cannot be used to advantage.

It should be noted that with the wedge blocks used as

shown in Fig. 32, the insulating of the switch rods and cross rail indicated in Fig. 18, is avoided.

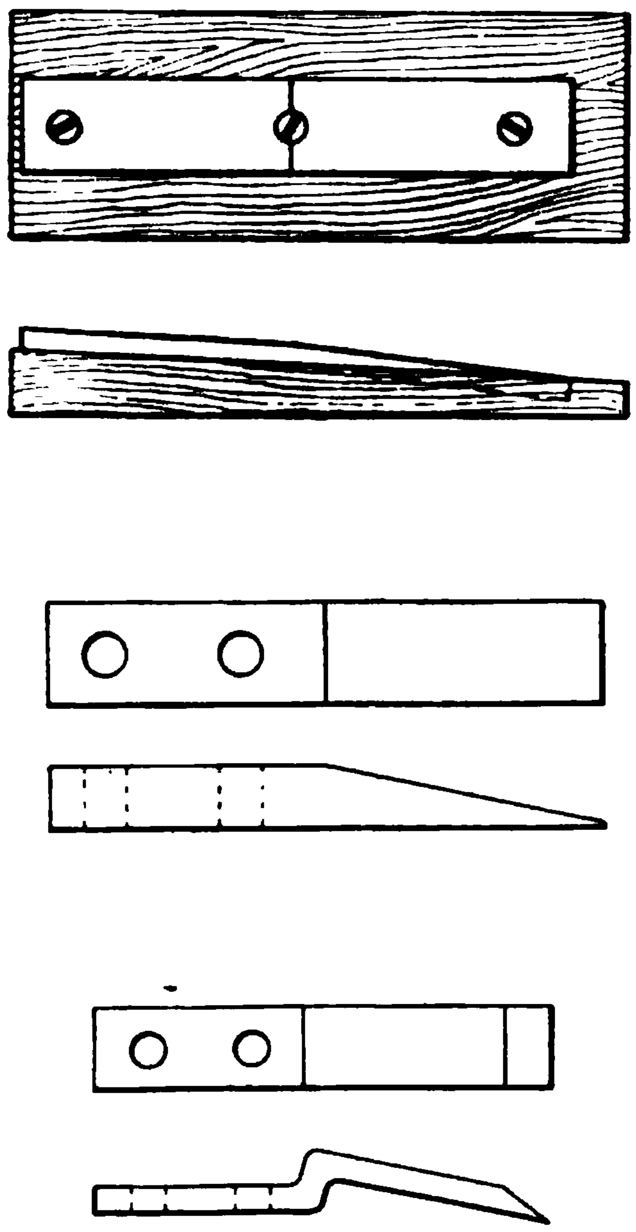


Fig. 33

37. As the switch rods must not be allowed to touch the stock rail on the side where the wedges are placed, it is usually necessary to offset them as shown.

As in its normal position the switch point is raised above the level of the stock rail, the possibility of interference with snow plows is sometimes considered an objection.

Although the wedge block is quickly and easily applied and convenient under some circumstances, its use must be considered as permissible rather than recommended practice, as it requires considerable attention to keep it in order.

38. Tie Plate Insulation: At interlocked switches where *tie plates* usually extend from rail to rail, as shown in Fig.

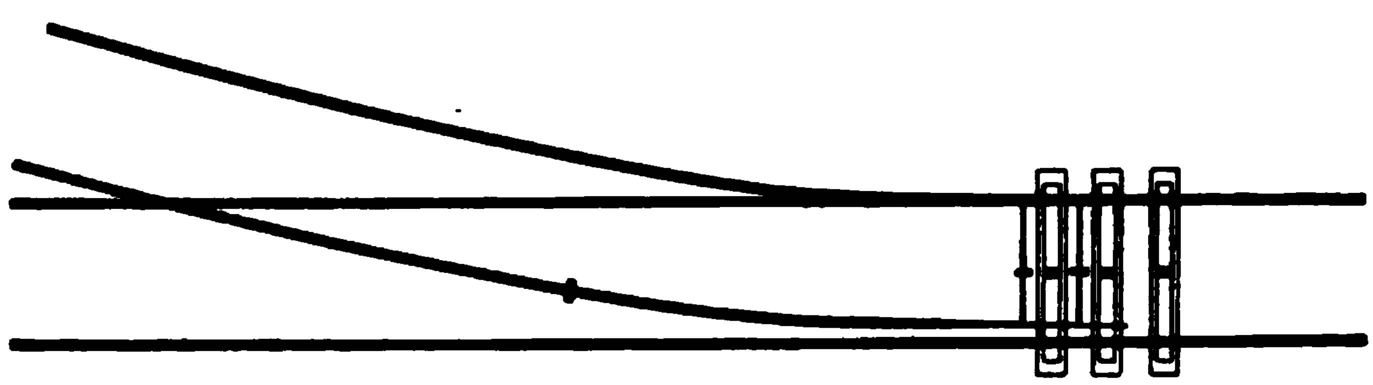


Fig. 34

34, it is necessary, when installing track circuits, to insulate them as indicated to prevent current passing from one rail to the other.

This may be done by cutting the tie plates, at the center and securing the ends with lag screws, as indicated in Fig. 35.

39. In Figs. 36-37 are illustrated insulated *lap joints* in tie plates. The former must be assembled in place whereas the latter can be assembled complete before being installed.

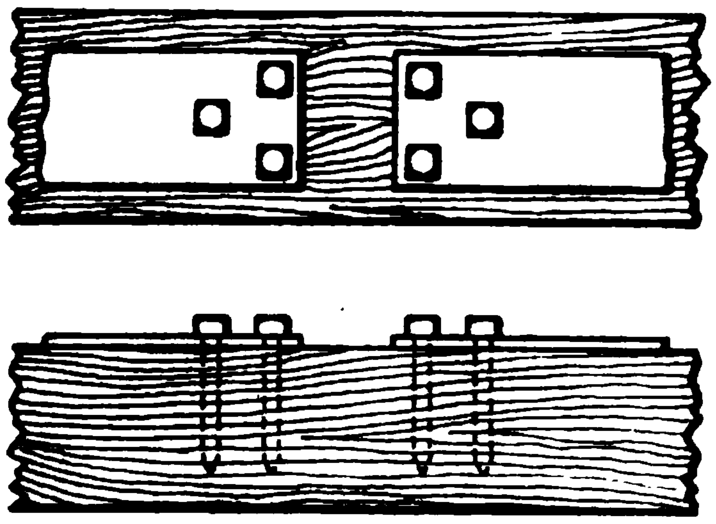
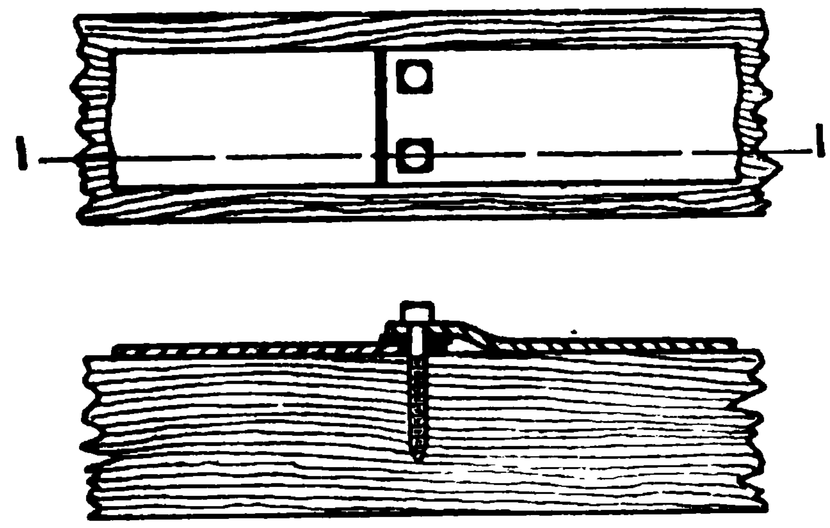


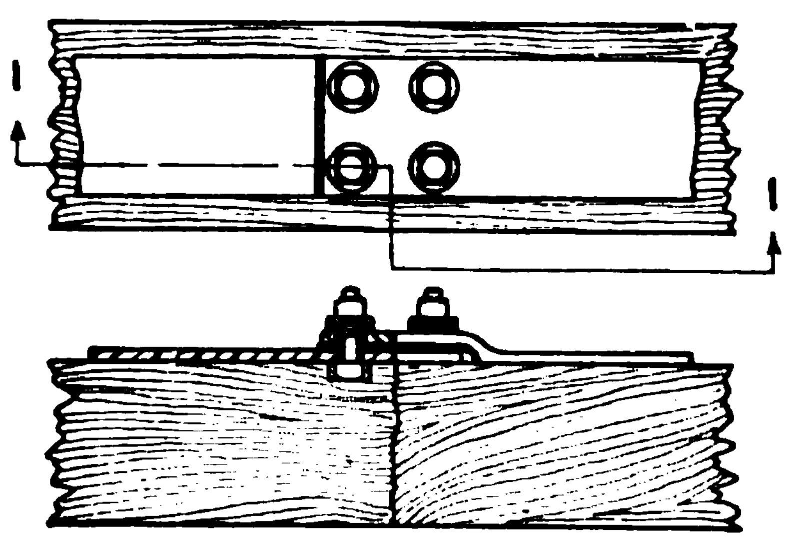
Fig. 35



SECTION I-I

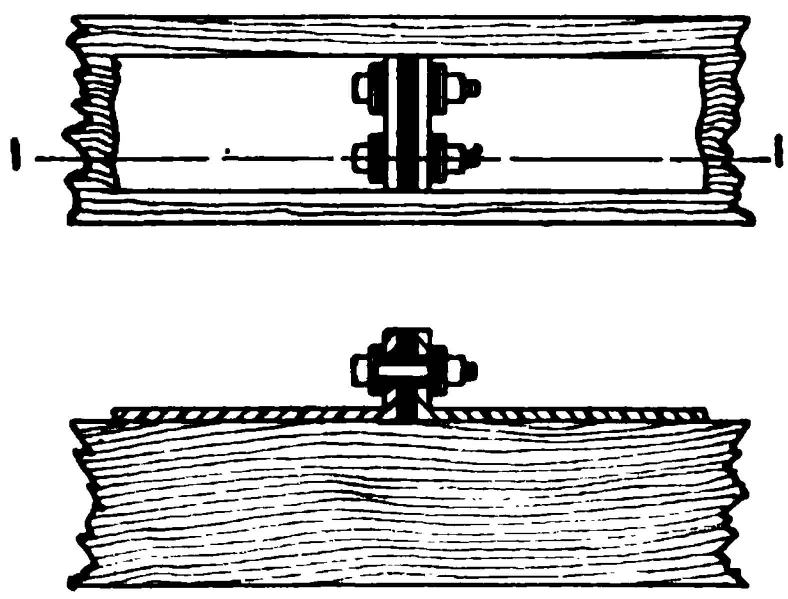
Fig. 36

40. Another type know as the *butt joint* and shown in Fig. 38 may be assembled, either in place or before installing.



SECTION I-I

Fig. 37



SECTION I-I

Fig. 38

41. Pipe Line Insulation: At mechanical interlocking plants where the switches, etc., are connected to the levers of the interlocking machine by pipe lines, it is frequently necessary, on account of the pipe being connected to apparatus in

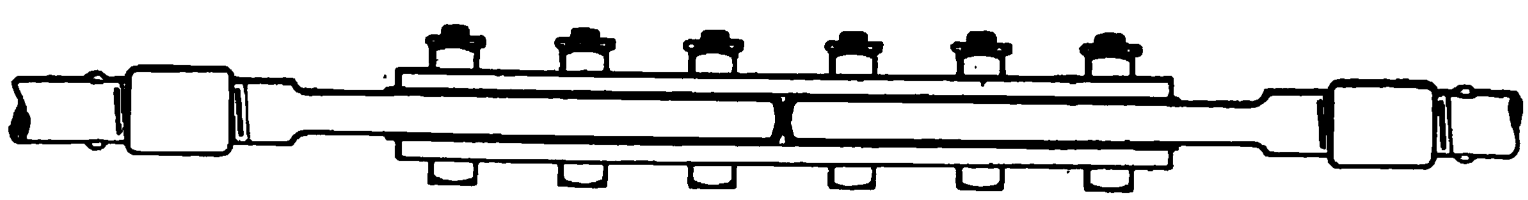


Fig. 39

contact with the rail, to insulate the pipe and thus prevent current from flowing between the pipe line and the rails. This

is accomplished by the use of pipe line insulation, types of which are shown in Figs. 39-41. As will be observed the joints

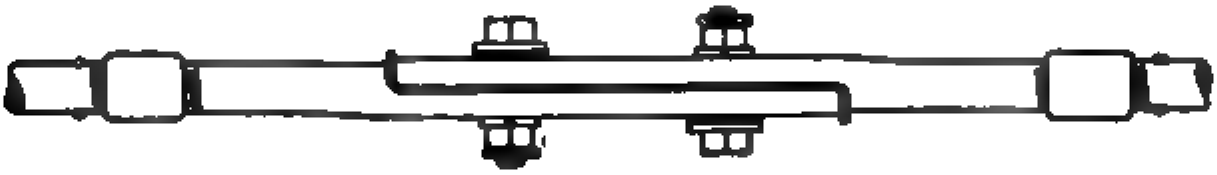


Fig. 40

shown in Figs. 39-40 are an adaptation of the types used in switch rod insulation any of which may be employed.

Fig. 41

42. In the joint illustrated in Fig. 41, the insulating material is *mica*, *heavy sheet mica* being placed between the parts under strain and the remaining spaces being filled with *molded mica* which seals the joint and protects the sheet mica from moisture.

43. Wire Line Insulation: Where mechanically operated signals are connected to the levers by wire, it is occasionally

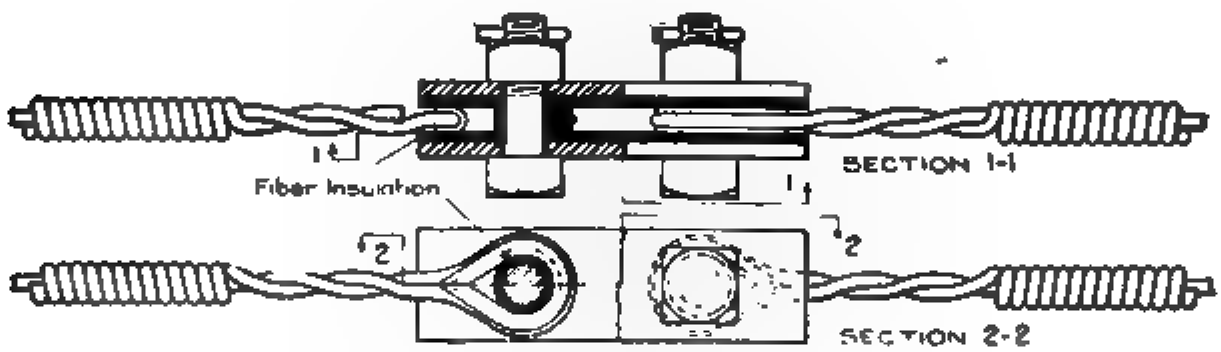


Fig. 42

necessary, when the wire is attached to apparatus connected with the rails, to insulate the wire connections from the rails. In Fig. 42 is illustrated one method used in such cases.

TRACK BATTERIES

44. The source of energy for D. C. track circuits is usually one or more cells of battery, either primary or storage, although current from a dynamo is used in some instances for this purpose.

PRIMARY BATTERIES

45. Primary batteries are the most common source of energy used on track circuits. Any type of *closed circuit* cells may ordinarily be used with good results, and to a limited extent, *open circuit* cells are available for this class of work.

46. Closed circuit Batteries: Among the types of closed circuit batteries, the **gravity cell*** has been generally adopted for the following reasons. Its freedom from polarization renders the full capacity of the cell available at all times, and its high internal resistance, limits the flow of current, thus preventing it from exhausting rapidly, when short-circuited**; in other words, it withstands continuous current output without becoming quickly exhausted.

47. The construction of the cell is simple and easily understood. It is readily set up, cared for and renewed; it is easily inspected and its condition may be quickly determined from its appearance. It is comparatively free from corrosive fumes and gases, which permits its use without any special precautions against the corroding of wires, iron shelters, etc.

48. This type of battery requires considerable attention which necessitates frequent disconnecting and connecting at the terminals and handling of the jars. This manipulation of the wires often causes them to break, sometimes inside the rubber covering where it is not at once discovered. In handling, a jar may be cracked and pass unnoticed until, after having been placed in service again, it causes a failure of the battery, several hours later, owing to the solution having leaked out of the cell. On this account, some engineers favor the use of earthenware or porcelain jars which are not as liable to crack as glass. Gravity battery also requires careful protection from low temperatures.

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*6″ x 8″.

**In the most common form of track circuit, the battery is practically short-circuited when a train is upon the conducting rails.

49. Other types of closed circuit batteries have been used to some extent. In some cases, on account of their low internal resistance, it is desirable to insert additional resistance in series with them in order to limit the flow of current when the track is occupied by a train.

50. Open circuit Batteries: These batteries are used with certain arrangements of track circuits. Various types are available for this purpose. Among them may be mentioned the several types of *salammoniac cells**, and also *dry cells*, the latter being especially adaptable on account of their general convenience in handling and because they require less protection from cold than many other batteries, although salammoniac cells are not much inferior to them in this respect.

51. It should be understood, that the use of *open circuit* batteries on track circuits is limited, compared with that of *closed circuit* batteries.

STORAGE BATTERIES

52. When circumstances permit their use, *storage batteries* provide a very satisfactory source of current for D. C. track circuits. As their internal resistance is very low, it is necessary to connect resistance in series with them, as an excessive flow of current would result in serious injury to the battery. They withstand low temperatures without special protection.

Fuses are sometimes used in connection with storage batteries to protect them, in case of a short circuit.

53. Resistances: In Figs. 43-44 are shown types of *adjustable resistances* adapted for use with track circuits. The *adjusting shunt* 1 in Fig. 43 is moved along the *bare resistance wire* 2 to the right or left to decrease or increase the resistance of the track circuit to suit local conditions.

In Fig. 44 the same result is obtained, the path of the current being as follows: From *wire* 1 through *binding post*

*The LeClanché cell may be considered typical.

2, to a coil of ***bare resistance wire*** 3. With ***adjusting shunt*** 4 removed the current will pass through the entire coil, to *adjusting screw* 5, to which the upper end of the coil is attached. The current then passes from the lower end of the adjusting screw through *connecting plate* 6 and *binding post* 7 to *wire* 8. With the adjusting shunt in the position shown, the current will pass only through the portion of the coil below its contact surfaces. From this point to the adjusting screw a *low resistance path* is formed through the adjusting shunt. Therefore the resistance of the circuit is varied by the raising or lowering of the adjusting shunt

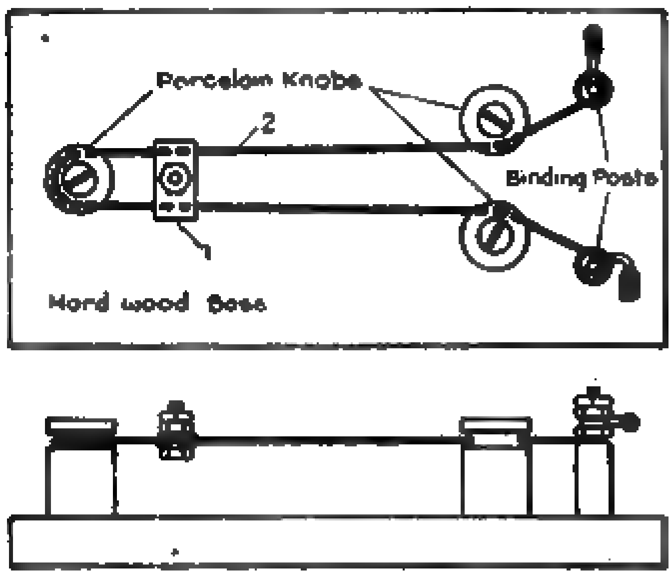


Fig. 43

54. *Fixed resistances,* wound on wooden or hard rubber spools, are frequently used. This type is sometimes supplied with a soft iron core, which increases its effect as a choke coil, thus assisting considerably in preventing the passage of lightning discharges*.

Fig. 44

55. **Charging Switches**: When charging storage batteries from a charging line, switches are employed, one type of which is shown, together with its wiring diagram, in Fig. 45.

It will be observed that *duplicate batteries* are used, one set being charged while the other is discharging to the track.

*The action of the choke coil is explained in Art. 82

The flow of current to the track must not be interrupted, therefore the *contact fingers* A are made long enough so that when the switch is being thrown to its opposite position, to

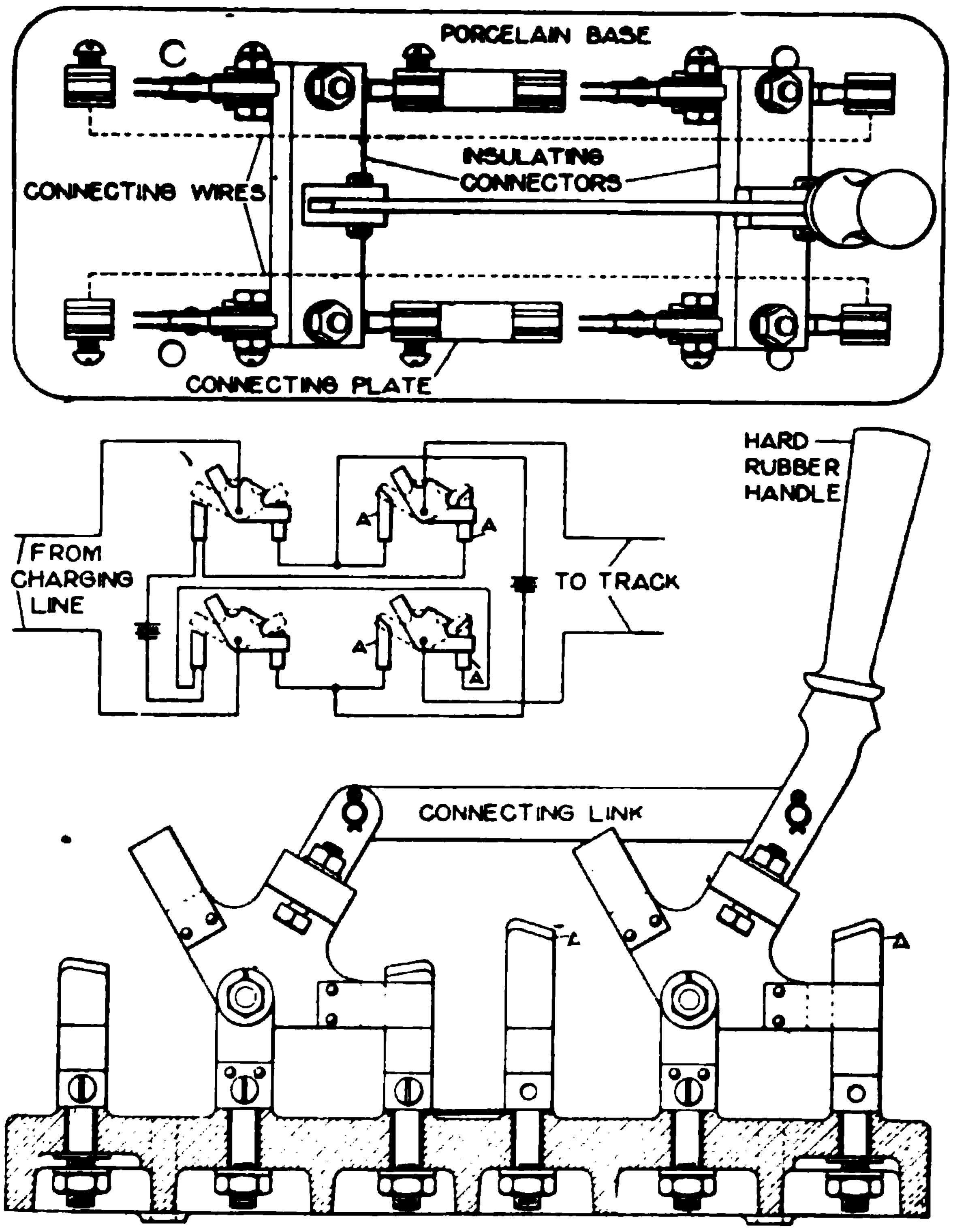


Fig. 45

reverse the charging of the batteries, contact will be made on one set, before contact is broken on the opposite set. This is shown by the dotted position of the springs in the diagram.

BATTERY SHELTERS

56. Where gravity batteries are used they must be protected not only from mechanical injury and interference, but also as already stated, from low temperatures. It is also desirable to protect them from evaporation although some ventilation is necessary.

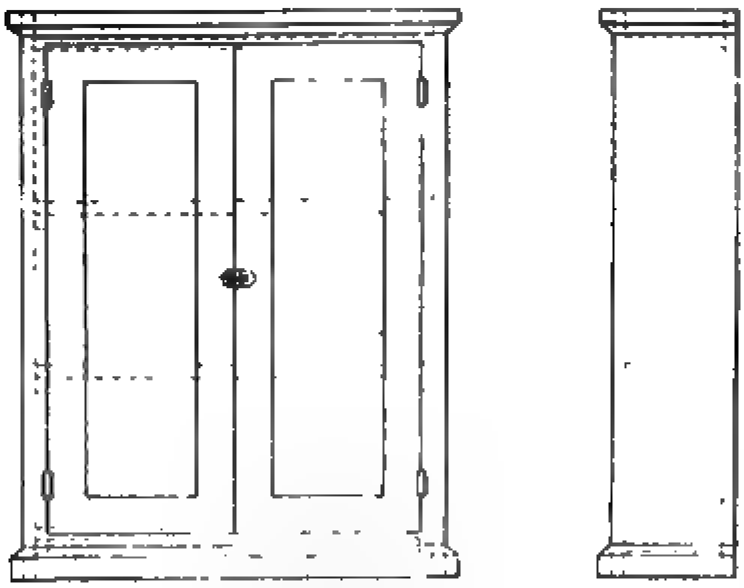


Fig. 46

57. Battery Cupboards: When a signal tower is conveniently situated, the track battery may be located in a *battery cupboard** in the building. This is usually an ordinary cupboard fitted with shelves, properly spaced for holding the cells. A suitable design is shown in Fig. 46.

Fig. 47 illustrates a *grooved shelf* which is used to some extent in battery cupboards. The object of the grooving is to prevent cracking of battery jars, assumed to be due to a difference in temperature between the bottom and sides of jars when placed on plain shelves. The grooves permit air to reach the bottom of the cells and thus tend to keep the bottom and sides at the same temperature.

Fig. 47

58. Battery Boxes: There are many instances, however,

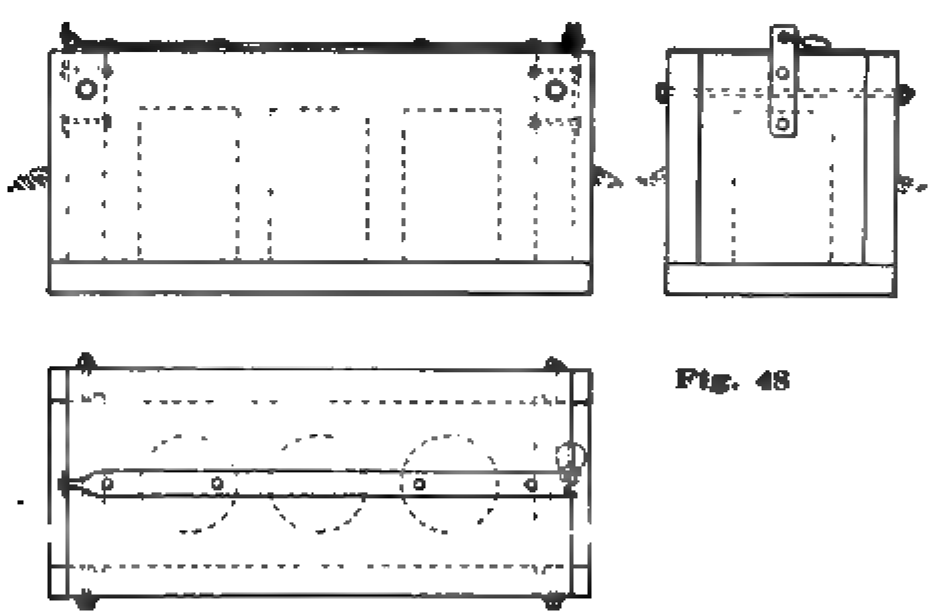


Fig. 48

*Also called *battery closet* and *battery case.*

where no building is convenient for housing track batteries. In such cases *battery boxes* or *battery chutes* are used. Fig. 48 illustrates a battery box for use in a warm climate. The box is made of wood and is set deep enough into the ground to keep it in place.

59. Fig. 49 shows a *cast iron box* used for the same purpose, which is provided with an additional bottom of wood,

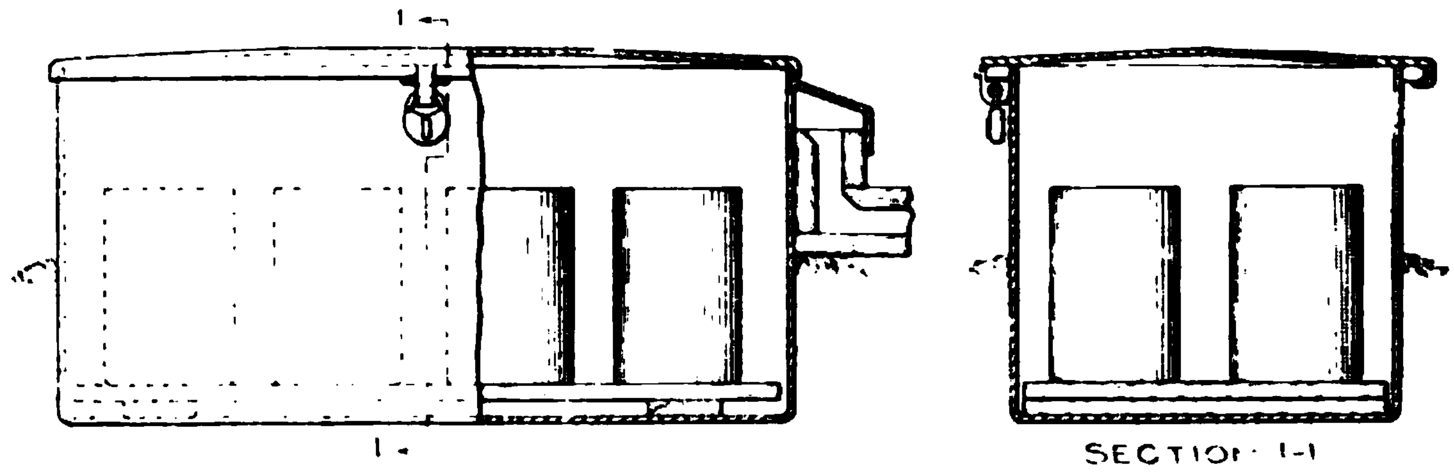


Fig. 49

it being undesirable to set the jars on iron, as contact with iron would produce a difference in temperature, which would be likely to crack them.

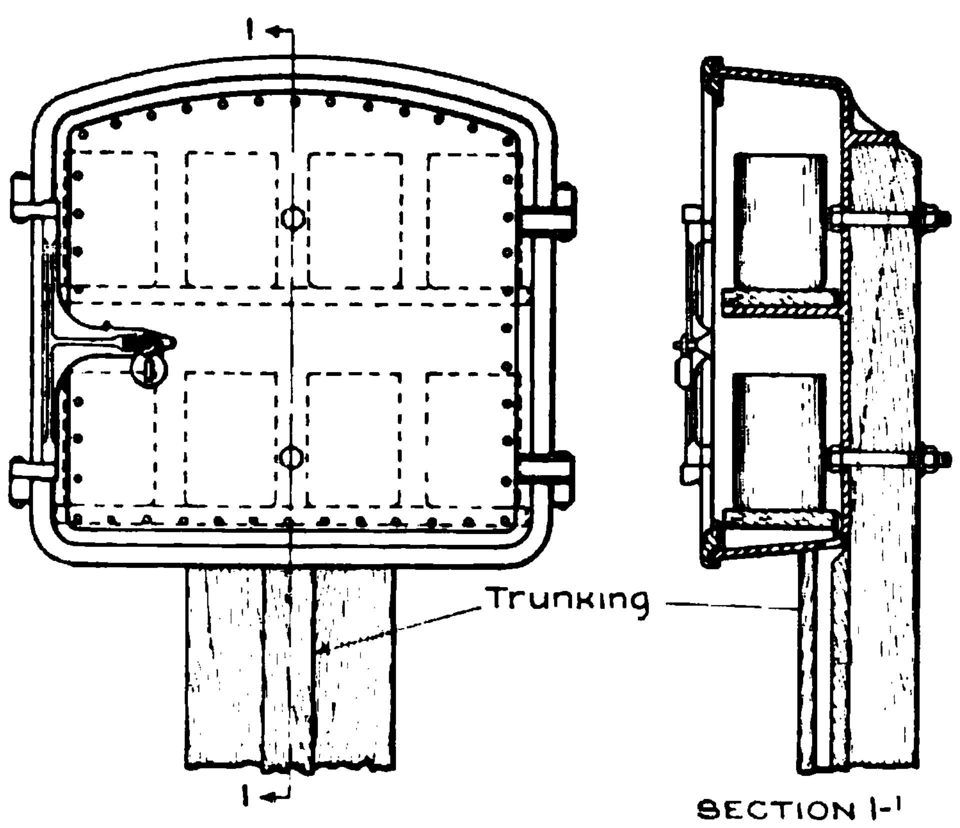


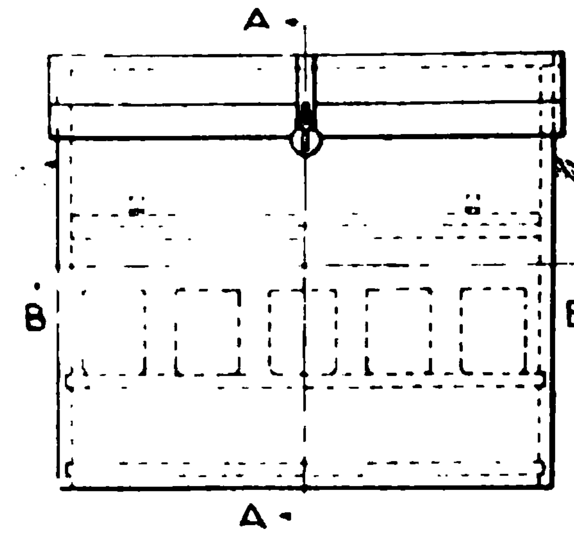
Fig. 50

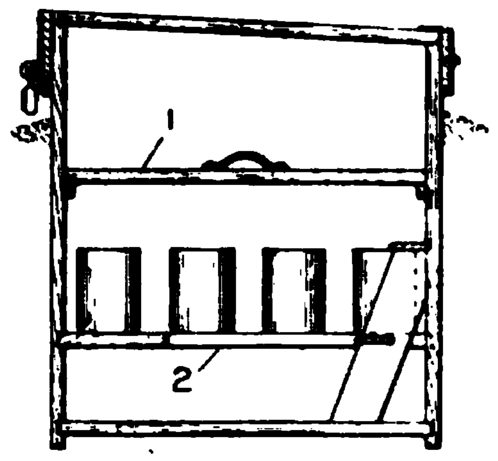
60. A type of battery box which is usually not as damp as those set into the ground is illustrated in Fig. 50. It is customary to use a post of hard pine, oak or chestnut, about eight feet long, set four feet into the ground.

61. If a few degrees of frost are to be guarded against, the battery box shown in Fig. 51 will give satisfaction. The warmth from the earth is retained in the box by the *frost board** 1, thus keeping the batteries at a

*Also called *frost cover* and *frost breaker*.

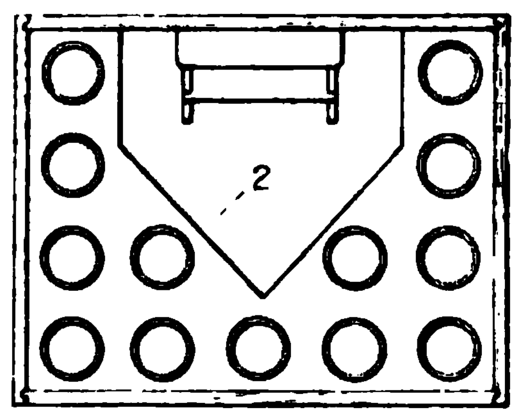
working temperature. The *false bottom* 2 on which the cells are placed, is kept in a dry condition and is thus prevented from rotting by the air space beneath it. This space also acts as a sump in case of leakage of water into the box.





SECTION A-A

The construction of this box is varied by the omission of the bottom and the use of slats for the false bottom. In case of a broken jar, the battery solution drains through the slats to the earth.



SECTION B-B

Fig. 51

62. Battery Chutes: If protection is to be provided against severe cold weather, other types of battery shelters must be employed. Usually the most convenient form for this purpose is the battery chute.

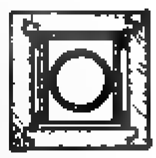
63. The *wooden battery chute* shown in Fig. 52 represents one of the earliest methods used to keep batteries from freezing. By lowering the cells deep enough into the ground they are maintained at a proper temperature by the warmth of the earth, assisted by the *frost board* 1.

The chutes are made of a good quality of white pine, cypress, yellow pine or oak, the joints being filled with white or red lead. They are occasionally built to hold twelve cells, or even more if desired, but, for track circuit work, it has usually been found more convenient to use chutes designed to hold not more than six or perhaps eight cells.

*Battery elevators** 2, are usually made of a good quality of white or yellow pine. They are arranged to hold from one to four cells but an elevator containing more than two cells is

*Also called *battery waiters.*

difficult to handle especially under unfavorably weather conditions. A vacant space in the elevator can be used to good advantage for storing a spare jar and is available if it should become necessary to increase the number of cells in the battery.



SECTION A-A

Fig. 52

The *rope* 3 which passes through the center of the frost board in addition to its principal use, that is, for lifting the elevator, also prevents the frost board from getting lost.

It should be long enough to allow the frost board to be lifted clear of the top of the chute without raising the elevator.

64. Battery chutes should be thoroughly painted on the outside and if subjected to considerable dampness, oiled or painted on the inside. The life of the elevator will be prolonged if oiled or painted, although this is not always done.

65. Under favorable conditions, that is, where the ground is dry and there is good drainage for surface water, probably the wooden chute may be considered as good a battery shelter for a small number of cells as can be provided.

In many cases however, it is necessary to locate chutes in wet places and it is sometimes difficult, especially in winter, to provide good surface drainage. Various means are employed to make wooden chutes water-tight, they are often covered with sheet metal, such as tin*, galvanized iron, zinc or lead, all joints being soldered. Tin rusts out quickly, being attacked on the outside by water, etc., and on the inside by battery solution spilled into the chute. Galvanized iron and zinc last somewhat longer but in time are consumed by the battery

*Tin-plate.

solution. Lead although expensive is much more durable and when properly applied and the chutes carefully handled has proven satisfactory. In practice, however, it is not easy to get them into place without starting some leak, usually caused when handling. Furthermore they are difficult to test for leaks.

66. With a view to overcoming the undesirable features of the wooden chute, *cast iron chutes,* types of which are shown in Figs. 53-54, have been brought into use, and to a large extent have superseded those constructed of wood. These are made *single* and *double* as shown, in lengths varying from 6 to 9 ft., the shorter being used in moderate climates and the longer where extreme cold weather is to be guarded against. In the double chute, a *wooden separator* is placed between the two elevators.

67. The elevators are made of wood. The *heads**, which are usually of white pine, cypress or fir, are sometimes made of two thin boards laid together with the grain at right angles. These are generally nailed together although they are sometimes glued. The slats are made of well seasoned oak or ash, free from knots. The number of slats varies from three to five; with fewer slats the connections are more accessible, whereas with a greater number, a stronger construction is obtained. The elevators are generally painted.

Fig. 53

Fig. 54

*Top, shelves and bottom

68. That part of the chute above the frost board is sometimes made rectangular and when so constructed provides a better space for storing battery material

The covers shown are detachable, being held in place by lugs, although they are often made with hinges The hinges sometimes become rusty and as a result work hard and are liable to break. Another fastening for the cover is shown in Fig. 55.

Fig. 55

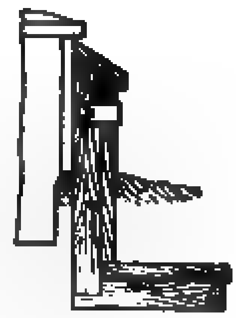
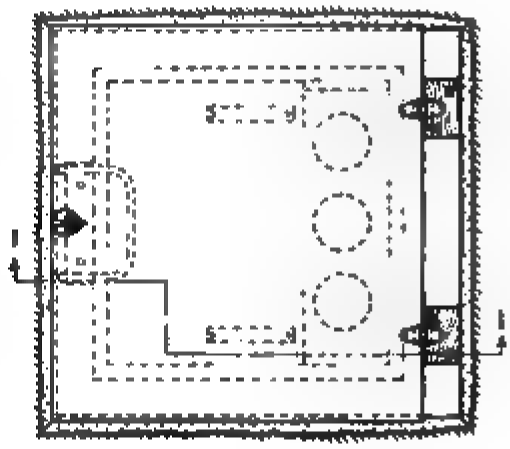


Fig. 56



SECTION I-I

Fig. 57

69. That part of the chute which covers the end of the trunking is known as a *trunking cap.* Although sometimes cast as a part of the chute it is frequently a separate casting, secured by bolts and spring washers, as shown in Fig. 54. The *trunking strap* illustrated in Fig. 56 is another method of attaching the trunking

70. Battery chutes constructed of *concrete* are sometimes used.

71. Battery Vaults: When a large number of battery cells are grouped together they can be conveniently located in a battery vault*, a type of which is illustrated in Fig. 57. In such vaults the warmth of the

*Also called *battery well, battery tub* or *tank, battery cellar* and *battery silo.*

earth is utilized to prevent the batteries from freezing, as explained in connection with chutes. They are built of wood, iron, brick and concrete. As battery vaults are mainly employed for housing batteries used in connection with other signal circuits, details of their construction will be explained hereafter.

Chutes and vaults are advantageous in comparatively warm climates, where there is little danger of freezing, as they keep the cells at an even temperature, thus tending to produce a uniform output.

72. Dry Battery Shelters: Dry cells may be put in any convenient place*, this being one of their best features, but they will last longer if kept where it is neither too dry nor too damp; in the former case, as for instance close to a stove or heater they lose moisture, a certain amount of which is necessary in the cell; in the latter case, the paste-board covers will become saturated and current will probably leak from the zinc casing, partially short-circuiting the cells. Dampness also tends to corrode binding posts and connecting wires.

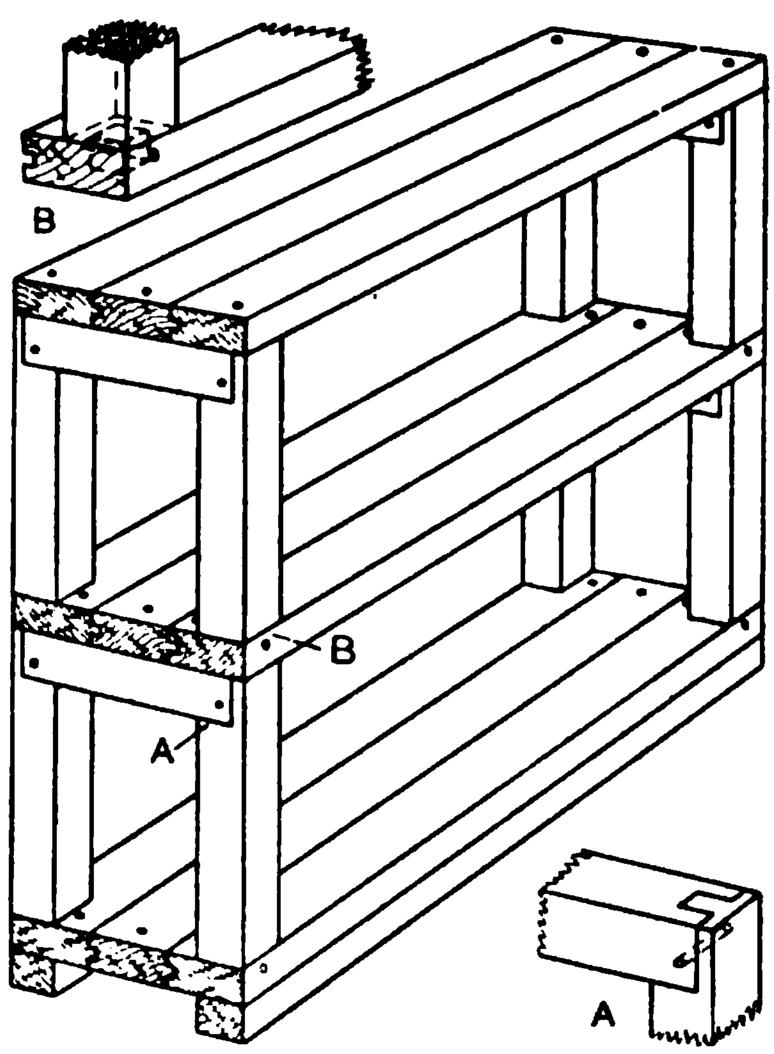


Fig. 58

73. Storage Battery Shelters: Storage batteries give off injurious gases and therefore when placed in ordinary buildings, arrangements must be made for ventilation.

Cupboards located outside are often used, as storage batteries are not seriously affected by low temperature**, and consequently no special arrangements are required to keep them warm.

The cells are quite heavy and therefore require a substantial rack to support

*See Fig. 76 for an arrangement of dry batteries.
See **Magnetism and Electricity—*Batteries*.

them, a typical design being shown in Fig. 58. As the fumes from the battery attack nails and bolts, the rack, as indicated in the figure, is fastened together by wooden dowel pins. Hard pine lumber should be used throughout, and when completed, the entire rack should be given at least two coats of acid-proof paint; in fact all woodwork about the cells should be thoroughly protected by this paint, from the fumes and spray which is given off by them.

74. When it is necessary to provide shelter for a few storage cells at isolated points along the track the concrete shelter illustrated in Fig. 59 may be used. The charging switches and resistances are placed on the table. The fumes and spray of storage cells soften concrete and therefore it is desirable to lay the floor of the vault with vitrified brick jointed with pitch, and to apply hot pitch to the walls.

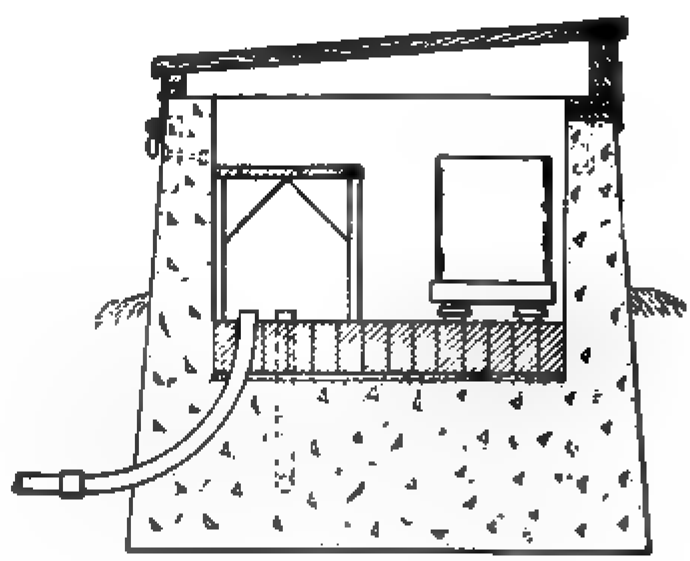

SECTION A-A

Fig. 59

LIGHTNING ARRESTERS AND TERMINAL BOARDS

75. To reduce the interference of lightning discharges with the operation of track circuits as much as possible, it is customary to protect the relays with lightning arresters*.

There are three devices or forms of apparatus ordinarily used to accomplish this purpose. They are: the *spark gap*, the *fuse*

*Also called *protectors*

and the *choke coil.* Some types of arresters represent only one of these features; others consist of combinations of them.

76. Spark Gap Arresters: A form of the spark gap arrester is illustrated in Fig. 60. Five *brass plates* having saw-tooth edges are mounted on a *wooden* (cherry or mahogany) *base* 1 as shown. The *middle plate* 2 is *grounded* and the wires leading to the relay are connected to the other plates (see diagram).

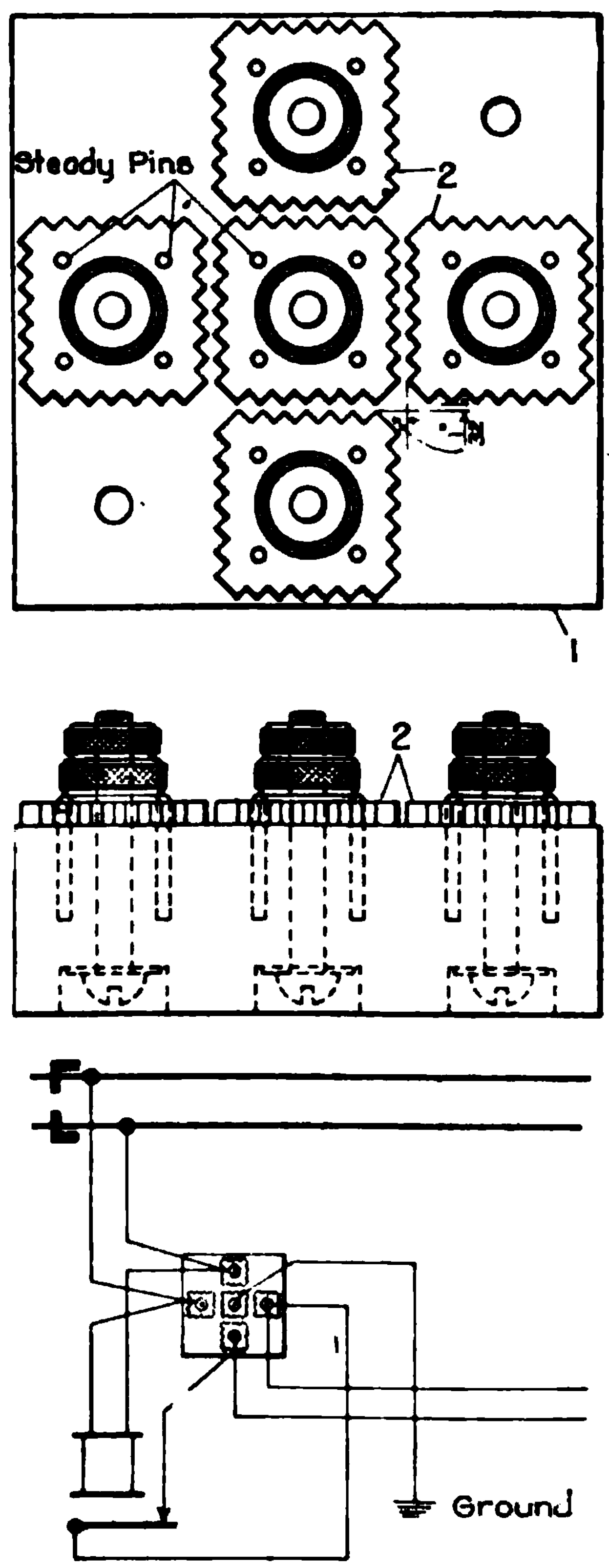


Fig. 60

As lightning disturbances tend to produce a high voltage between the wires and the earth, an arc is formed across the gap to the ground plate, and the excessive potential is thus discharged. The *saw-teeth* on the plates assist in forming the arc. The plates are placed far enough apart so that the ordinary working voltage will not *hold* the arc; therefore as soon as the excessive voltage is discharged the arc is *broken* and the normal operation of the circuit is restored.

As wood is liable to be carbonized* by an arc, thus making electrical connection between the plates and therefore permanently grounding the circuit, a channel is frequently cut in the wood beneath the saw-teeth. Better results may be secured by the use of slate or porcelain for the base.

In this form of arrester the saw-teeth are liable to be melted off by the heat of the arc, so that after the arrester has been in service for some time the space between the plates may be considerably increased and it will require a much higher voltage to start the arc, thus decreasing the efficiency of the arrester.

*Formed into charcoal.

77. Another form of spark gap arrester is shown in Fig. 61. In this type, pairs of *carbon blocks* 1 separated by pieces of *perforated mica* 2 are clamped between the *brass springs* 3 and the *ground plate* 4. The springs are connected to the *contact strips* 5, the wires leading to the relay, being attached as shown. The base is made of porcelain or slate, the holes in the bottom being sealed with insulating wax thus excluding moisture which is liable to corrode the binding screws. The wax also assists in holding the screws in place.

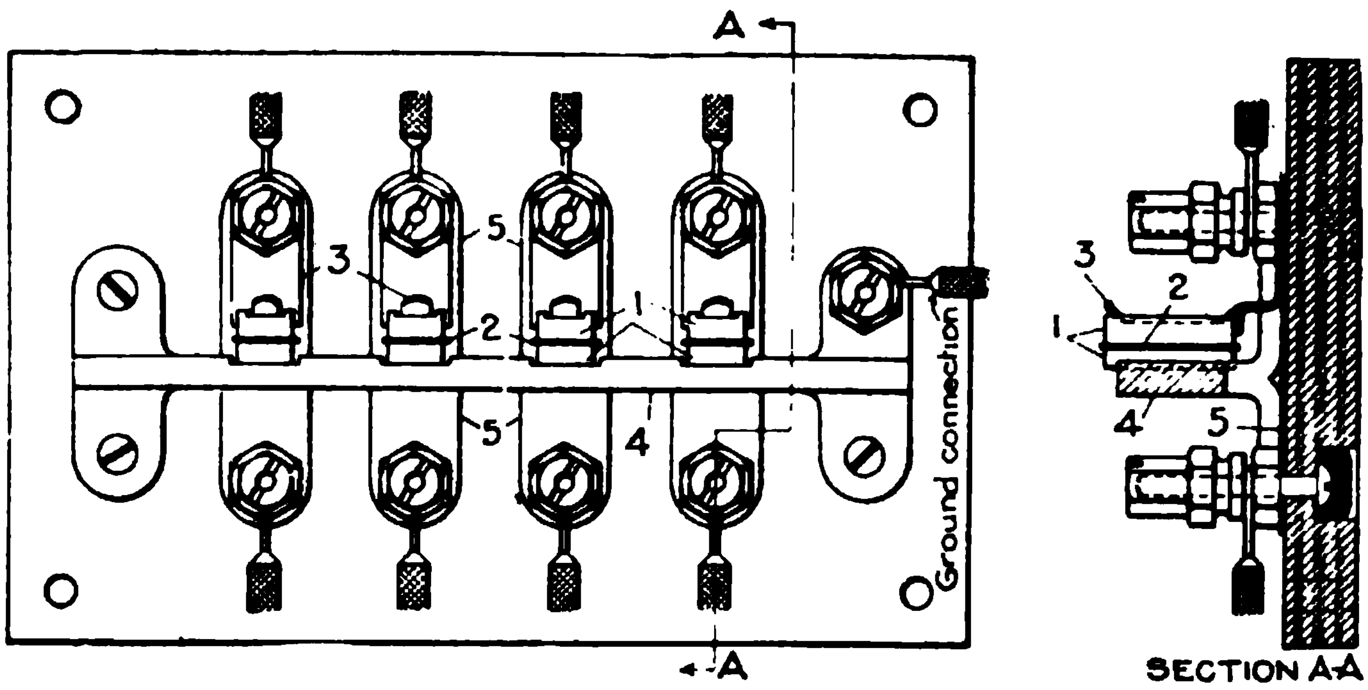


Fig. 61

As carbon is a conductor, and as the sheet of mica is quite thin, (about $\frac{1}{32}$ in.) the gap is small and easily spanned by an arc in case of excessive voltage.

It is practically impossible to melt carbon, and therefore a much more uniform space is maintained than with the saw-tooth arrester. The carbons and mica are removable and therefore can readily be inspected and cleaned.

A single *carborundum block* is being used in place of the two carbon blocks, the mica being omitted. Thus the circuit is continually grounded through the carborundum block, but as the resistance of this material is high, the operation of the signal devices is not disturbed; at the same time a suitable ground for lightning discharges is provided.

78. Fuses: The high voltage produced by lightning disturbances frequently causes an excessive flow of current through circuits in which relays are placed. To protect the instruments from this current, fuses are sometimes inserted in the wires leading to them. Of course, after a fuse has been blown it must

be replaced before the circuit can be used again. On this account their use is sometimes considered undesirable. It is apparent that the capacity of a fuse should be at least equal to the maximum operating current.

79. One of the simplest forms of fuses* used in signal work, and the manner in which it is applied to protect the relay is

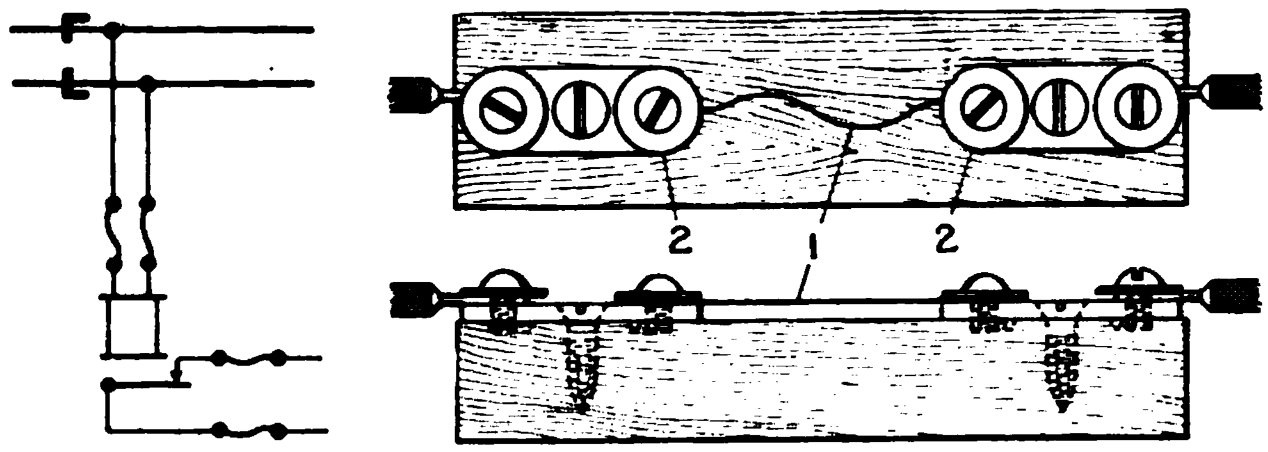


Fig. 62

shown in Fig. 62. The *fuse wire* 1 between the two *terminals* 2 is usually made of an alloy of *lead and tin*, which has a comparatively high resistance and a low fusing temperature.

The arrangement shown in Fig. 62 is objectionable for the following reasons: First, exposure to mechanical injury. Second, fuse wire used for this purpose will, if exposed to moisture, be diminished considerably in cross-section by oxidization, and, its carrying capacity being thus reduced, it is liable to be blown by the operating current. Third, fuses made from the lead-tin alloy are soft and easily broken, and will melt if momentarily exposed to any common source of heat such as a burning match.

80. Another arrangement, known as the *mica fuse*, is shown in Fig. 63. The *fuse wire* 1 is covered with varnish or shellac and placed either on one side of a *mica plate* 2 or between *two* mica plates, thus being protected from mechanical injury and from moisture. The ends of the fuse-wire are connected to *thin copper bands*

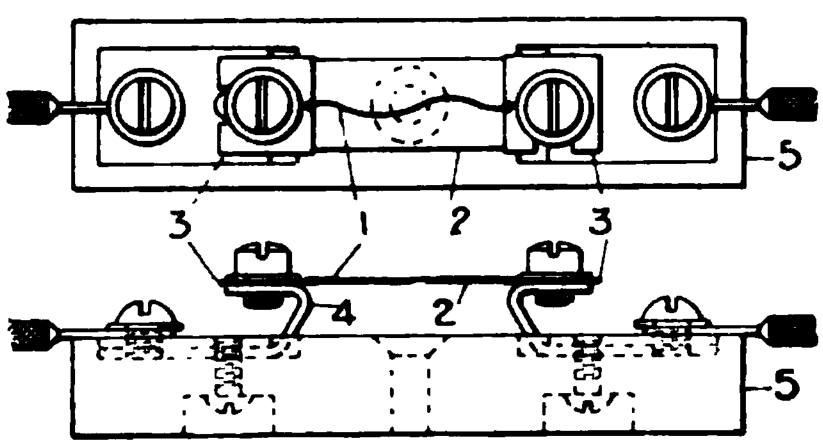


Fig. 63

*Also called *spider wires*.

3, which are slotted so as to fit conveniently into the *terminals* 4. The base 5 is usually made of porcelain or slate.

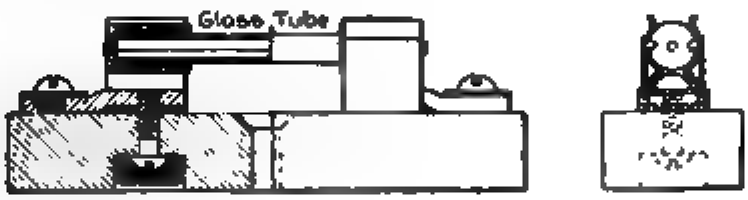


Fig. 64

81. Another method of protecting the fuse wire is to place it inside a *glass tube* as shown in Fig. 64. Cartridge fuses are sometimes used in connection with lightning arresters.

82. **Choke Coils:** A choke coil* lightning arrester is shown in Fig. 65. Several turns of *tinned copper wire* 1 are wound on a *porcelain tube* 2, which contains a *soft iron core* 3. One of these coils is cut in** on each wire leading to the relay.

Lightning disturbances usually appear in the form of high frequency alternating current, which in passing through the turns of the coil develops a large amount of *reactance*†. This effect is greatly increased by the presence of the soft iron core. The coil therefore, although offering very little resistance to the signal current, *chokes off* the lightning discharge. Bare wire is used for the coil and a *ground plate* 4 is provided, thus producing a spark gap to relieve the discharge. The base 5 is made of porcelain or slate.

A

Ground

SECTION A-A

Fig. 65

83. **Combination Arresters:** A lightning arrester combining the spark gap, fuse and choke coil, is illustrated in Fig. 66. Such combinations are used, as it is assumed that when so arranged the arrester will be more effective in overcoming lightning disturbances.

*Also called *kicking coil.*
**Inserted so as to become a part of the circuit.
†See **Magnetism and Electricity.**

With this type the soft iron core is omitted and the number of turns in the choke coil increased. The spark gap is between

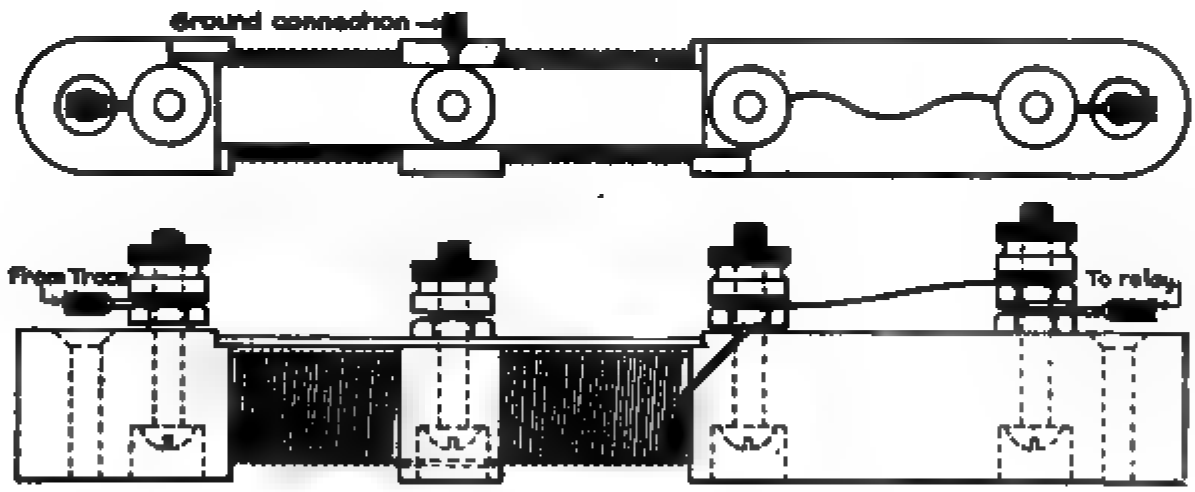


Fig. 66

the turns of wire in the coil and ground plate, as in Fig. 65. The block is made of porcelain.

84. Another combination of the three devices is shown in Fig. 67, in which the choke coil and ground plate are similar to those illustrated in Fig. 65. Other spark gaps are arranged on each side of the *saw-tooth plate* 1 using additional *ground plates* 2 and 3.

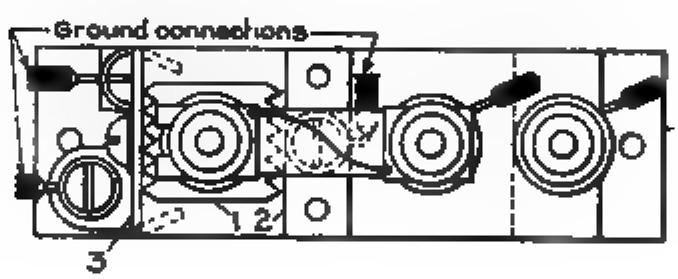


Fig. 67

85. In Fig. 68 is shown an arrester in which the choke coil is wound on a *glass tube* 1, inside of which is a *closed coil* 2 of many turns of wire. The *ground plate* 3 is covered with *perforated mica* 4 to prevent accidental grounding of the circuit on account of some conducting substance getting between the plate and the coil. A copper tipped *link fuse* 5 is shown. *Metal blocks* 6, which sup-

Fig. 68

port the glass tube, also assist in discharging to the ground plate.

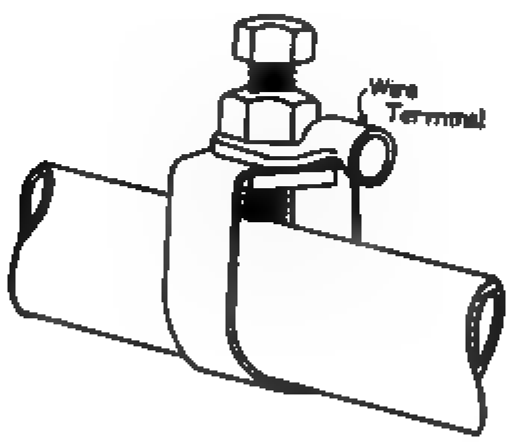


Fig. 69

86. Grounds: For the successful operation of the lightning arrester, a good ground connection must be secured.

When a water pipe is accessible, as is frequently the case at signal towers, it is common practice to ground on to it, using a *ground clamp*, such as is shown in Fig. 69.

87. When there is no convenient water pipe, a *ground rod*, made of ½ to 1 in. galvanized iron about 8 ft. long, is driven into the earth and the ground wire soldered to the top of it.

88. Water pipes and ground rods are not always satisfactory, the *ground plate** shown in Fig. 70 being considered a better arrangement, although more difficult to install. The plate is made of annealed copper and should be at least 18 in. square, and $\frac{1}{16}$ in. thick, being

Fig. 70

*It should be noted that the term *ground plate* has two different applications.

thoroughly tinned to avoid corrosion. A bare tinned copper wire, usually from 10 to 20 ft. long, not smaller than No. 6, B & S G., is soldered or brazed to the plate*. The wire is sometimes riveted to the plate, and then soldered or brazed. The plate when in place is surrounded by crushed charcoal or coke**, (about pea-size), which collects and retains moisture, thus insuring a good ground connection.

89. Terminal Boards: When the lightning arresters are placed at some distance from the relay, as frequently occurs in a tower, or in case no arresters are used, it is common practice to install brass terminals† mounted close to the relay, as a convenient means of identifying the wires and also for attaching the solid wires used in the ordinary wiring to the flexible leads which are connected to the binding posts of the relay Such an arrangement is represented diagramatically in Fig. 71.

Fig. 71

90. In many cases the *brass terminals* are mounted on the inside of the relay box for this purpose, as shown at A, Fig. 72, but better results are obtained by the use of a separate block

Fig. 72

with the terminals mounted upon it, known as a terminal board, as shown at B in the same figure. The block may be made from well seasoned oak or cherry and is often oiled after it is bored

*When brazed, the plate should be tinned after the brazing is completed.
**Locomotive smoke-box cleanings are suitable
†Also called *terminal strips.*

for the terminals, although they are sometimes impregnated with paraffin or other suitable material, to exclude moisture and thus insure good insulation.

91. In Fig. 73 is illustrated a *slate terminal board.* In

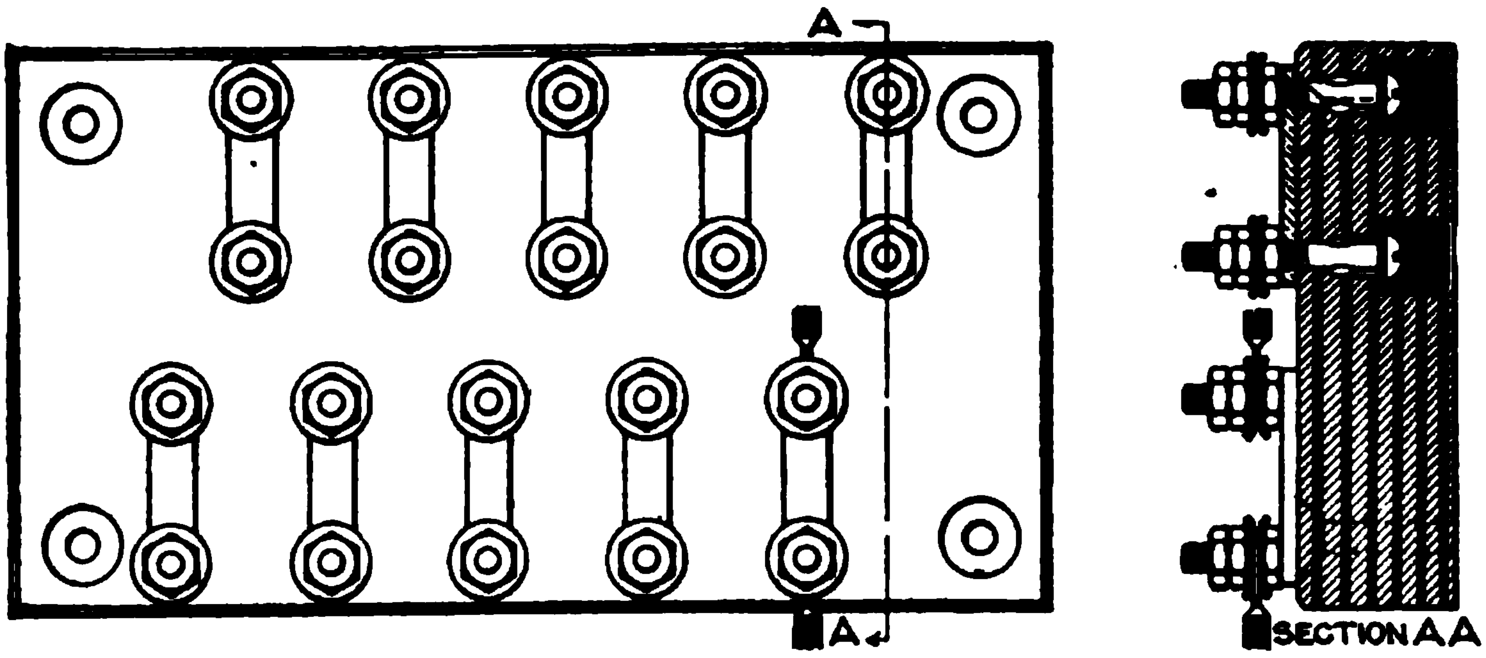


Fig. 73

the type shown the terminals, which are flat brass plates, are staggered to allow the wires to pass directly across the board.

RELAY SHELTERS

92. In order to obtain good service from track relays it is necessary to protect them from the weather, dust, moisture and from interference.

93. Relay Cases: When relays can be placed inside of buildings, it is usually desirable to do so. When so located a relay case*, a type of which is shown in Fig. 74, is employed.

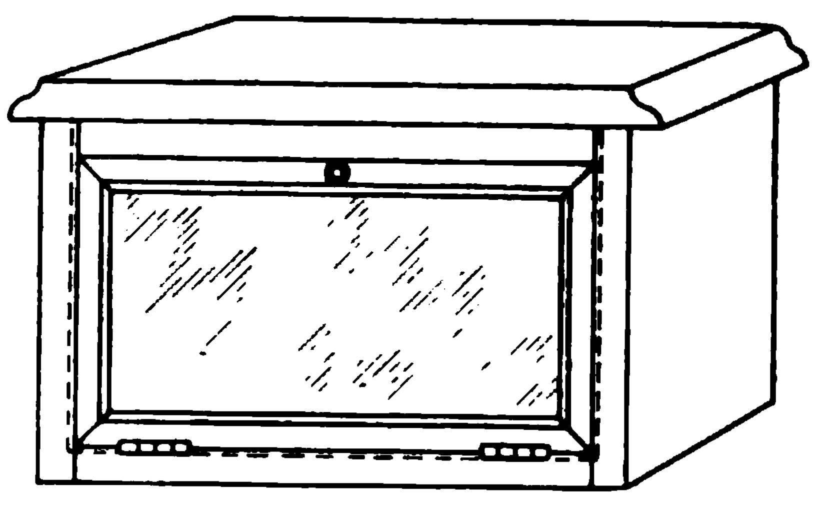


Fig. 74

If more than one shelf is required, the door is either hinged on one side of the case, or is made in two parts opening in the middle. Space should be provided for the terminal board, and also for the lightning arresters if they are to be placed in the relay case.

*Also called *relay cupboard.*

94. Relay Boxes: When there is no building conveniently situated, it is necessary to provide a relay shelter that is weatherproof. Suitable shelters for this purpose are constructed of wood and iron.

95. A *wooden relay box* is illustrated in Fig. 75, mounted on a *relay post* 1. The relay is placed on the shelf and the space

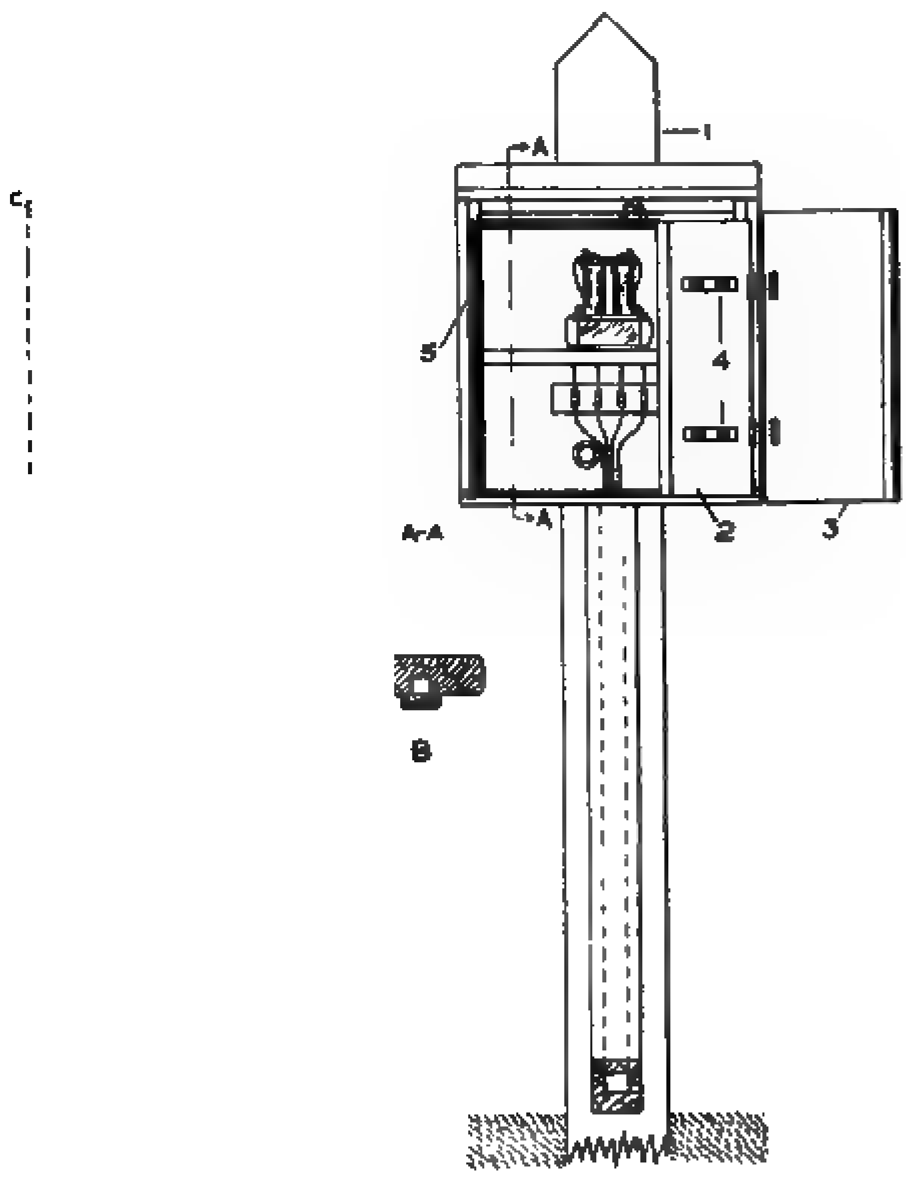


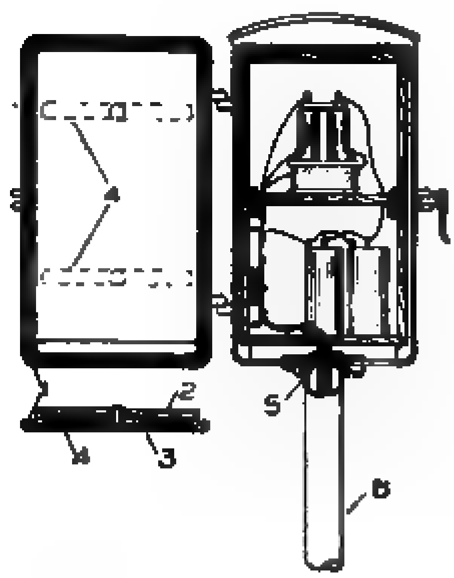
Fig. 75

below is used either for the lightning arresters or terminal board as shown, or for another relay. The *inner door** 2 provides additional protection against the weather and dust. When the

*Also called *frost door*.

outer door 3 is closed it compresses the *flat brass springs* 4 on the inner door, which force the latter tightly against the *felt gasket* 5 on the door stop.

Wooden relay boxes are usually constructed from a good quality of white pine, the joints being filled with white lead. The interior of the box is painted with two coats of white paint and the outside with two coats of paint of suitable color.



In some cases the interior is coated with oil instead of being painted, as it is thought that in case metallic paints were used, grounding or short-circuiting might occur.

As indicated by dotted lines, two relay boxes may be mounted on the same post.

The *wooden posts* upon which relay boxes are mounted are made of hard pine, chestnut or oak. The boxes are usually secured to the posts by bolts as shown or by wood screws.

In sketch B, Fig. 75, is shown a relay post having a groove for carrying wires up the post to the relays. This arrangement obviates the necessity for using the vertical trunking.

Fig. 76

96. *A cast iron relay box,* mounted on an *iron relay post*, containing a relay, lightning arresters and cells of dry battery, is illustrated in Fig 76. If desired the post may be set in the ground, the concrete foundation being omitted.

The tendency of moisture to collect on metal surfaces* makes it desirable to line the inside of these boxes with wood as shown.

*Commonly called "sweating"

The groove in the edge of the door is fitted with a *rubber* or *felt gasket* 1 to exclude dust and moisture. The *inner door* 2

A Fig. 77 b

is mounted on studs fastened to the *iron door* 3 with *brass springs* 4 between them.

Hard wood or hard rubber *bushings* 5 are fitted into the small openings in the *relay post* 6, so that the wires will not be injured when being drawn into place.

97. In some cases the post, instead of extending into the foundation, is leaded into a cast iron base which is secured to the top of the foundation by anchor bolts as shown at A, Fig. 77. This type of post is also set on oak foundations, as shown in sketch B.

98. Other methods of mounting iron relay boxes are shown in Fig. 78. In the arrangement shown at A, the relay post is bolted on to a battery chute in place of the trunking strap. (Fig. 56). In some instances wooden relay boxes are attached to the iron relay post instead of the iron box, as shown. Sketch B illustrates a relay box bolted to an iron signal post.

Fig. 78

TRUNKING AND CONDUIT

99. In order that the wires, which form a part of the track circuit, may be protected from mechanical injury and also to some extent from moisture, they are placed together in a wooden casing, called *trunking* or in fiber tubing known as *conduit.*

100. Trunking: Inside of buildings the type of trunking* shown at A, Fig. 79, is employed. The board used as a cover

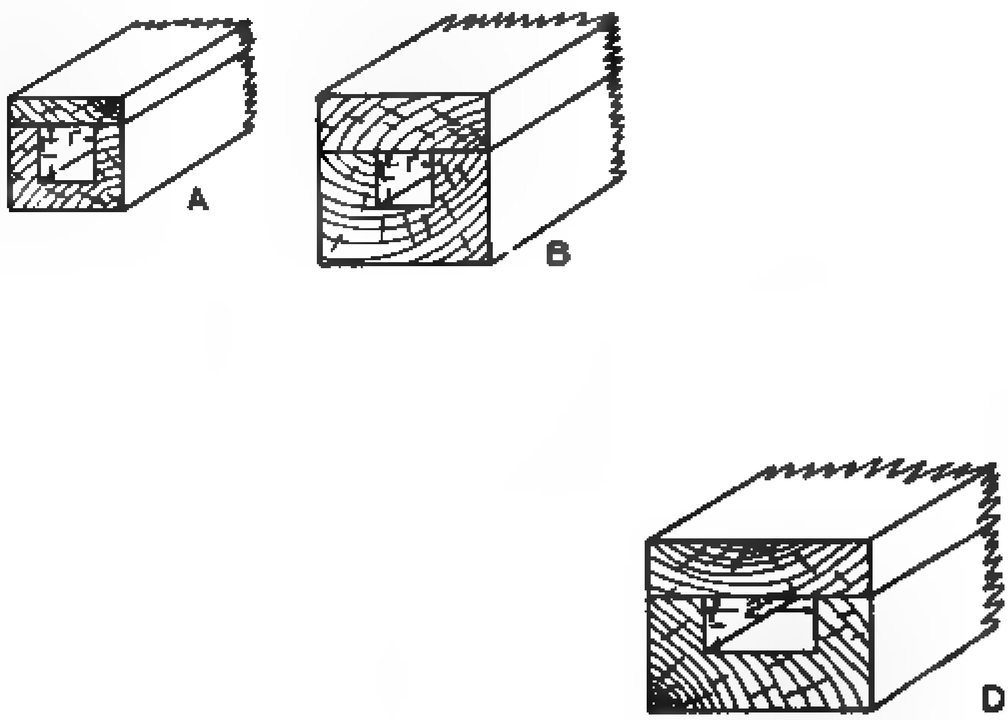


Fig. 79

is called *capping.* This trunking is made of white pine or cypress in 10 to 16 ft lengths.

101. Outside of the buildings where better protection is required, the type shown at B is used. It will be observed that the groove is the same size, but the walls are much thicker. This type is made of white pine, cypress, fir, yellow pine and redwood, usually in the same lengths as the smaller trunking. It is sometimes treated with creosote or other wood preservative.

102. Where greater capacity is necessary the types shown at C and D are substituted.

*Also called *grooved lumber.*

103. If a still larger size is required it may be made in the foregoing manner, but is often constructed with four separate pieces of lumber as shown at E, being known as *built up trunking.*

Trunking is *finished,* except on the inside, and capping on all sides.

104. In order to provide better protection for the wires, they are sometimes surrounded with a *pitch compound,* after being laid in the trunking. This compound excludes moisture and furthermore it is thought to protect the insulation from being affected chemically by treated trunking. It should have a low melting point (200 deg. Fahr. or less) in order that it will not burn the wire insulation. It also should not become brittle in extreme cold weather.

105. Trunking Stakes: When trunking is installed on or above the surface of the ground it is supported on stakes, Fig. 80, generally made of unfinished white oak or hard pine. Round white cedar stakes, tapered, are also used for this purpose. Stakes should be long enough to extend at least 2 ft. into the ground.

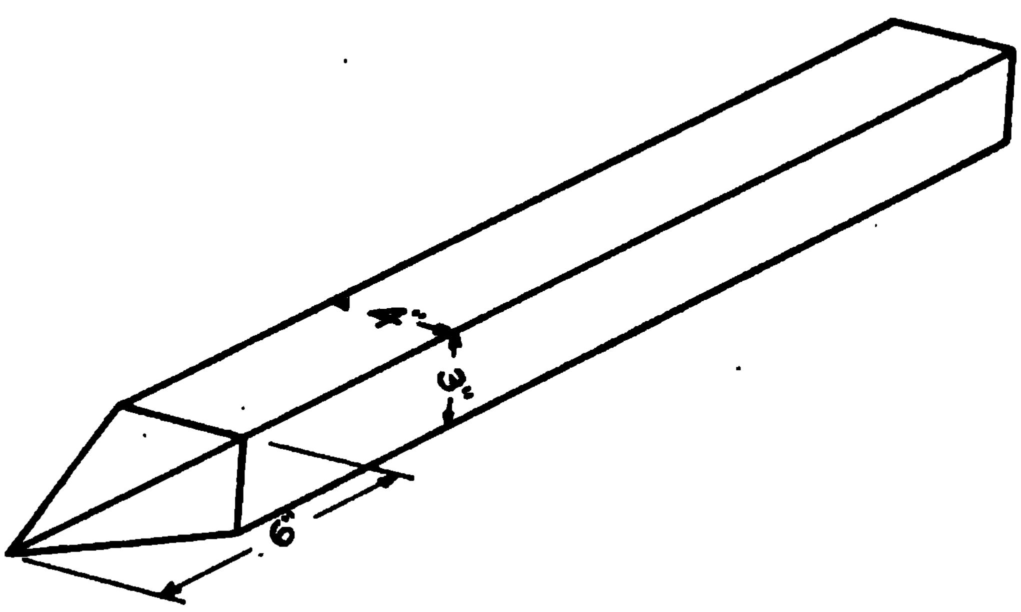


Fig. 80

106. Conduit: Bituminized* fibre conduit shown in Fig. 81, is used to some extent in place of trunking. It is waterproof and is not attacked by acids or alkalies.

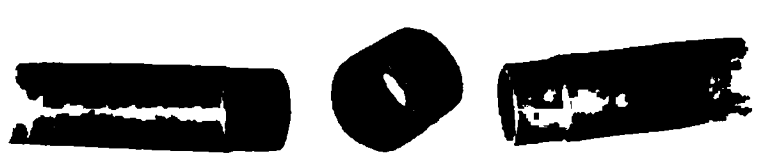


Fig. 81

Two methods are used in making joints: First with sleeves, either tapered as shown, or threaded; and second,

*Impregnated with *bitumen*. See **Materials.**

by a socket joint arranged directly on the lengths of conduit. A sealing compound, either white lead and linseed oil, or hot tar, is sometimes used in making the joints as an additional protection against moisture.

This conduit is furnished in sizes from 1 to 4 in. inside diameters and usually in lengths of from 2½ to 7 ft. The thickness of the wall varies from ¼ in. to ½ in. Bends, tees, crosses, caps, junction boxes, etc., are made of the same material.

EXAMINATION QUESTIONS

(1) What is a track circuit?

(2) How are adjacent rail lengths electrically separated?

(3) What is an end post?

(4) (*a*) What is a rail bond? (*b*) Why are they necessary?

(5) Name two kinds of wire used for rail bonds.

(6) Why should bond wires be tenacious?

(7) State two methods of attaching bond wires to the rail.

(8) When are large types of rail bonds necessary?

(9) Is mechanical strength an important feature of an insulated rail joint?

(10) What purpose does fiber serve in an insulated rail joint?

(11) Why is it impossible to place the outside wood, shown in Fig. 7, on the inside of the rail?

(12) What are fiber bushings and fiber washers used for?

(13) Describe the probable result, assuming that an insulated rail joint similar to that shown in Fig. 10 were installed without the fiber washers.

(14) How are insulated rail joints arranged for use on frogs having guard rails?

(15) Why are switch rods insulated?

(16) Why is comparatively low insulation resistance satisfactory on track circuit work?

(17) Would you recommend the use of wedge blocks?

(18) Is it advisable to have the bushings in insulated switch rods extend through the fiber plates?

(19) Why are front rods insulated.

(20) What may be considered the simplest means to prevent current from passing from rail to rail through the tie plates?

(21) What insulating materials are used in pipe line insulation?

(22) What is the necessity for employing series resistance with storage batteries when used on track circuits?

(23) Why is the gravity cell generally used for track circuit work?

(24) Under what conditions would you use the following type of battery shelters: (*a*) Battery chutes, (9 ft.). (*b*) Battery boxes. (*c*) Battery cupboard.

(25) How is trunking secured to iron battery chutes?

(26) What is a battery elevator?

(27) What is the purpose of the frost board?

(28) Why is it necessary to protect concrete from storage battery solution?

(29) What is a lightning arrester?

(30) Explain the action of a choke coil.

(31) Why is the mica fuse better than the fuse shown in Fig. 62?

(32) Why is coke placed around the ground plate shown in Fig. 70?

(33) How are the connections made between the flexible wires, which are attached to the binding posts of a relay and the solid wires leading into the relay box?

(34) From what kinds of material are terminal board bases made?

(35) What kind of shelters are used for relays placed in buildings?

(36) What is the object of placing felt or rubber gaskets on relay box doors?

(37) What is trunking used for?

(38) Why is trunking, for use in buildings, made of lighter material than that used in outside work?

(39) What is the difference between grooved and built-up trunking?

(40) What is fiber conduit?

PRINCIPLES OF OPERATION

NORMALLY CLOSED TRACK CIRCUITS

107. The operation of the **normally closed track circuit** is outlined in Art. 1. There are a number of features in connection with this arrangement which will now be considered in greater detail.

NOTE.—There are two reasons for the designation **normally closed**, which are briefly, as follows: First, because, in operation, the battery is always on *closed* circuit, either through the relay or through the wheels; and second, because, in its *normal* position (when the track is not occupied by a train), the relay is *closed*.

108. It will be observed that the track circuit represented in Figs. 82-83, a duplicate of that shown in Fig. 1, is made

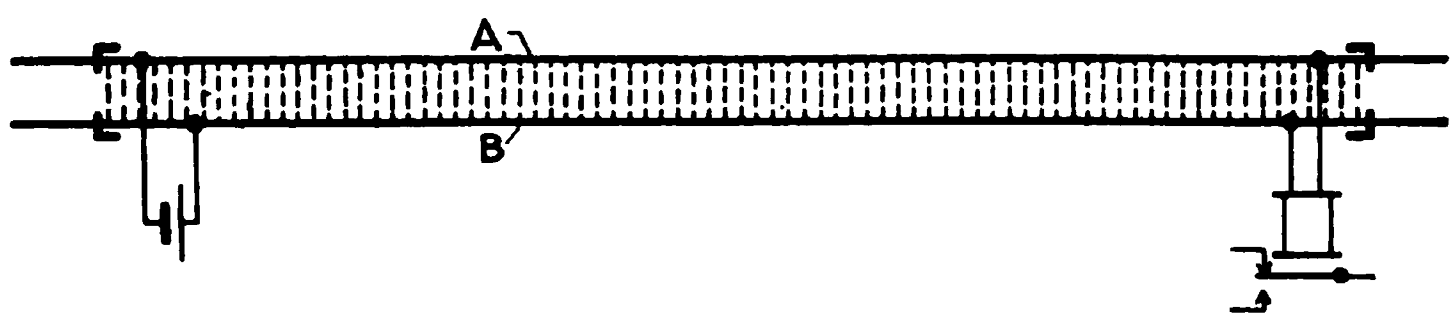


Fig. 82

up of four principal elements as follows: *1st.* A **source of energy**, in this instance a cell of primary battery. *2nd.* The **running rails** of the track, *electrically connected* by rail bonds

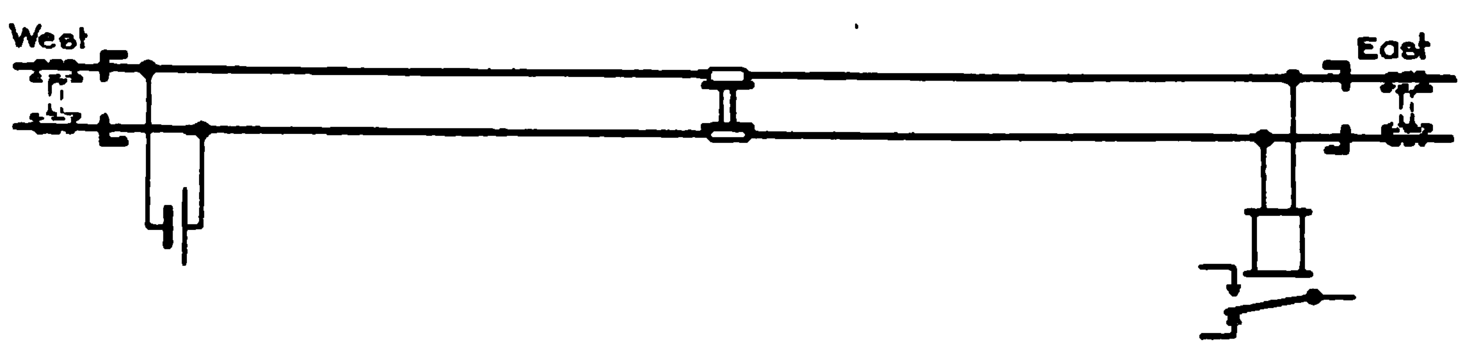


Fig. 83

to *insure* the passage of current from one rail length to another, and *electrically separated* by insulated rail joints from the adjacent rail lengths, at the ends of the section, to *prevent* the passage of current. *3rd.* A **relay***, whose coil or coils are so

*As noted in Art. 1 other instruments than relays are used, although rarely.

connected as to form part of the circuit. *4th.* One or more **pairs of wheels**, including the axle, or axles, joining them, of any car, locomotive or train, occupying the track whose rails form part of the circuit, these wheels and axles making good electrical connection from one rail to the other.

In addition to these four principal elements there are two other important factors which ordinarily enter into the consideration of the track circuit. They are: *1st.* A *resistance in series* with the source of energy (internal resistance of the battery, or artificial resistance placed in series with it). *2nd.* The *conductivity* of the *ties* and *ballast.*

109. It is apparent that the *limits* of the track circuit are determined by the location of the insulated rail joints. If the wheels shown in Fig. 83 are moved to a position *beyond* the insulated joints (as shown dotted), they will then have *no effect* on the circuit.

The effect of the wheels is practically the same whether they are *standing* still, or *moving* in either direction. If the normal direction of train movement, in Fig. 83, is from *east* to *west,* the battery is said to be feeding *against traffic.* If, on the other hand, the normal direction of train movement is from *west* to *east,* the battery is said to be feeding *with traffic.*

110. Series Resistance: As the operation of the normally closed track circuit depends upon the current being shunted out of the relay through the wheel and axles, it is evident that without some resistance (either internal or artificial) other than the wiring, in series with the battery, there would be practically nothing to limit the flow of current when the track is *occupied,* and therefore the battery would in most cases, rapidly become exhausted. Also owing to the large current flow, the relay would probably receive enough current to prevent it from releasing.

111. Ballast Resistance: If the rails were well insulated from each other, in other words, if there were no *leakage* of current from rail A to rail B, Fig. 82, through the ties and ballast, the amount of current flowing through the relay* when

*That is, through the *coils* of the relay. This expression will be so understood throughout this part.

the track is *unoccupied,* could be determined at once by applying Ohm's law.* For instance, with a battery having an effective E. M. F. of 1 volt, and an internal resistance of 1 ohm, (disregarding the resistance of the rails and wiring) the current through a 4-ohm relay would be calculated as follows:

$$I = \frac{E}{R} \text{ or } I = \frac{1}{1+4} = .2 \text{ amp. or } 200 \text{ mil-amp.. } \textit{Ans.}$$

In practice, however, the foregoing condition never exists. An *additional path,* as indicated by dotted lines in Fig. 82, is formed through the ballast, a certain amount of the current from the battery passing through it instead of through the relay. The *resistance* of this path is a variable quantity, governed principally by the condition of the track. For instance, after a period of hot dry weather it will be *higher* than after a long heavy rain. With clean rock ballast, well clear of the rails, it will be *higher* than with clay or cinder ballast, especially if the latter is allowed to come into contact with the rails.

Under *uniform track conditions* it is evident that this *ballast resistance* will be inversely proportional to the length of the track circuit; that is, if it is 10 ohms per 1,000 ft., it will be 5 ohms per 2,000 ft., etc. However, in practice, this rule must not be followed too closely, on account of lack of uniform resistance of ordinary roadbeds. If this resistance is allowed to get below a certain point it will take so much of the current away from the relay that the latter will fail to *pick up* its armature when the wheels leave the circuit.

112. Calculations: In order to determine the effects of various conditions upon the operation of the track circuit, the rules for calculating the flow of current in multiple circuits have been arranged in formulas, as follows:

E = Effective E. M. F. of battery, *in volts.*

b = Internal resistance of battery plus artificial resistance in series with same (when used**), *in ohms.*

r = Resistance of relay, *in ohms.*

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*See **Magnetism and Electricity.**

**As before noted, with certain types of batteries the use of artificial resistance is necessary.

n = Ballast resistance, *in ohms.*

s = Resistance from rail to rail through wheels and axles, *in ohms.*

I = Current output from battery, *in amperes.*

i = Current through relay, *in amperes.*

113. The resistance of the rails* and also that of the wiring is generally so small that it *may be neglected;* if, however, a *considerable length* of wire is used, the resistance of that between the battery and the rails, should be added in as a part of b, and that, between the rails and relay, as a part of r.

When calculations are being made for long track circuits, especially where the bonding is not in the best of condition, it may be desirable to allow for the difference in voltage at the opposite ends of the circuit, due to the resistance of the rails* and bonding.

114. As the operation of the relay is dependent upon the current flowing through it, the formulas have been arranged with a view to obtaining this value (i), under various conditions.

To find the current output from the battery when the track is *unoccupied* the following formulas are used;

$$I = \frac{E}{b + \dfrac{nr}{n + r}}. \qquad (1)$$

To find the current passing through the relay when the track is *unoccupied;*

$$i = I\frac{n}{n + r}. \qquad (2)$$

By substituting in formula (2) the value of I given in formula (1), we obtain the formula;

$$i = \frac{E}{b + r + \dfrac{br}{n}}. \qquad (3)$$

Formula (2) is used to advantage to find the value of i, when

*The resistance of a 30 ft. steel rail, weighing 80 lbs. to the yard, is less than .00042 ohms.

the value of I can be conveniently obtained by measurement. Formula (3) is employed when the values of E and b are known.

115. To illustrate the use of these formulas the following values are assumed:

$$E = 1 \text{ volt.}$$
$$b = 1 \text{ ohm.}$$
$$r = 4 \text{ ohms.}$$
$$n = 10 \text{ ohms.}$$

It is also assumed that the 4-ohm relay is adjusted to *pick up* at 65 mil-amperes and *release* or *drop away* at 30 mil-amperes.

Using these values in formula (1),

$$I = \frac{1}{1 + \frac{10 \times 4}{10 + 4}} = .2593 \text{ amp., } Ans.$$

Therefore the current output from the battery when the track is unoccupied, is 259.3 mil-amperes.

Using this value for I in formula (2),

$$i = .2593 \times \frac{10}{10 + 4} = .1852 \text{ amp., } Ans.$$

Therefore the current passing through the relay when the track is unoccupied, is 185.2 mil-amperes.

The same result is obtained by using formula (3), as follows;

$$i = \frac{1}{1 + 4 + \frac{1 \times 4}{10}} = .1852 \text{ amp., } Ans.$$

Thus, under the assumed conditions, the relay is supplied with current *above* its *pick-up* point, and therefore its armature is *raised*, against the *front* contact points, as shown in Fig. 82.

116. PROBLEMS.—In the following problems it is assumed that the track is *unoccupied*.

(1) With the values given in Art. 115, with the exception that a 9-ohm relay is used: (*a*) What will be the current output from the battery? (*b*) What current will pass through the relay?

(2) If the current output from the battery is 260 mil-amperes, and the ballast resistance 15 ohms: (*a*) What current will pass through a 5-ohm relay? (*b*) Through a 3½-ohm relay?

(3) Assuming the following conditions: Effective E. M. F. of battery 2 volts; internal resistance of battery, 3 ohms; resistance of relay, 4 ohms; ballast resistance, 3 ohms: (*a*) What is the current output from the battery? (*b*) What current will pass through the relay?

(4) Assuming that a 4-volt storage battery is employed, the internal resistance of which is low and therefore may be ignored: How much current will pass through a 12-ohm relay, with the artificial resistance in series with the battery, adjusted to 8 ohms, and a ballast resistance of 40 ohms?

ANSWERS.—(1) (*a*) 174.3 mil-amp. (*b*) 91.7 mil-amp. (2) (*a*) 195 mil-amp. (*b*) 211 mil-amp. (3) (*a*) 424.2 mil-amp. (*b*) 181.8 mil-amp. (4) 178.6 mil-amp.

117. To find the current output from the battery when the track is *occupied* by the wheels of a train (Fig. 83), the following formula is used;

$$I = \frac{E}{b + \dfrac{nrs}{nr + ns + rs}}. \qquad (4)$$

To find the current passing through the relay when the track is *occupied;*

$$i = I\,\frac{ns}{nr + ns + rs}. \qquad (5)$$

Substituting in formula (5), the value of I given in formula (4), and reducing;

$$i = \frac{E}{b + r + \dfrac{br}{n} + \dfrac{br}{s}}. \qquad (6)$$

118. To illustrate the application of formulas (4) to (6) inclusive the values given in Art. 115, are assumed, together with the following:

$$s = .01 \text{ ohm.}$$

Substituting these values in formula (4);

$$I = \frac{1}{1 + \dfrac{10 \times 4 \times .01}{(10 \times 4) + (10 \times .01) + (4 \times .01)}} = .9901 \text{ amp., } Ans.$$

Therefore the current output from the battery, when the track is occupied is 990.1 mil-amperes.

Using this value for I in formula (5),

$$i = .9901 \times \frac{10 \times .01}{(10 \times 4) + (10 \times .01) + (4 \times .01)} = .0025 \text{ amp., } \textit{Ans.}$$

Therefore the current passing through the relay, when the track is occupied, is 2.5 mil-amperes.

The same result is obtained by using formula (6), as follows;

$$i = \frac{1}{1 + 4 + \frac{1 \times 4}{10} + \frac{1 \times 4}{.01}} = .0025 \text{ amp., } \textit{Ans.}$$

Thus, under the assumed conditions, although the current is not entirely cut off from the relay, by the presence of the wheels, the amount which continues to pass through the coils, is considerably *below* the *drop-away* point of the relay; consequently, its armature is *released* and rests against the *back* contact point, as shown in Fig. 83.

119. PROBLEMS.—In the following problems it is assumed that the track is *occupied* by a train.

(1) With the values given in Arts. 115 and 118, with the exception that a 9-ohm relay is used: (*a*) What will be the current output from the battery? (*b*) What current will pass through the relay?

(2) Assuming that the battery consists of two gravity cells, the effective E. M. F. of which is 1 volt and the internal resistance of each 2.5 ohms, connected in multiple:* What will be the current through a 4-ohm relay, when the ballast resistance measures 75 ohms and the shunt formed by a train is estimated at .03 ohms?

(3) The current output of a certain track battery measures 1,100 mil-amperes: Find the amount of current passing through the relay (resistance 5 ohms), if the ballast resistance measures 18 ohms and the shunt resistance is estimated at .05 ohm.

ANSWERS.—(1) (*a*) 990.1 mil-amp. (*b*) 1.1 mil-amp. (2) 5.8 mil-amp. (3) 10.9 mil-amp.

120. The assumed values used in the foregoing calculations, may be considered as typical for ordinary conditions found in practice, but, as already stated, there is a wide variation in these conditions.

*See **Magnetism and Electricity** for calculating voltage and internal resistance of batteries.

When making calculations for any particular circuit, its *ballast resistance,* should be determined by measurements taken, either on the track under consideration, or on a track where the conditions are as near the same as possible.

The resistance from rail to rail, through the wheels and axles, is of course a variable quantity, the value of which is altered considerably by sand, ice, or rust, on the rails or wheels, and also by the weight of the car forming the shunt. Car wheels that are not equipped with brake shoes are considered somewhat less effective in shunting, than those which receive brake shoe wear.

121. On account of *leakage* that occurs through the ties and ballast, of ordinary track circuits, the voltage which can be satisfactorily applied to the rails, is limited; the amount of energy available to operate any instrument connected into the circuit being approximately that required to actuate a relay armature.

122. Broken Rail Protection: Incidental to the operation of the track circuit is its ability to detect broken rails. If the rails were well insulated from the ties and ballast, a break or

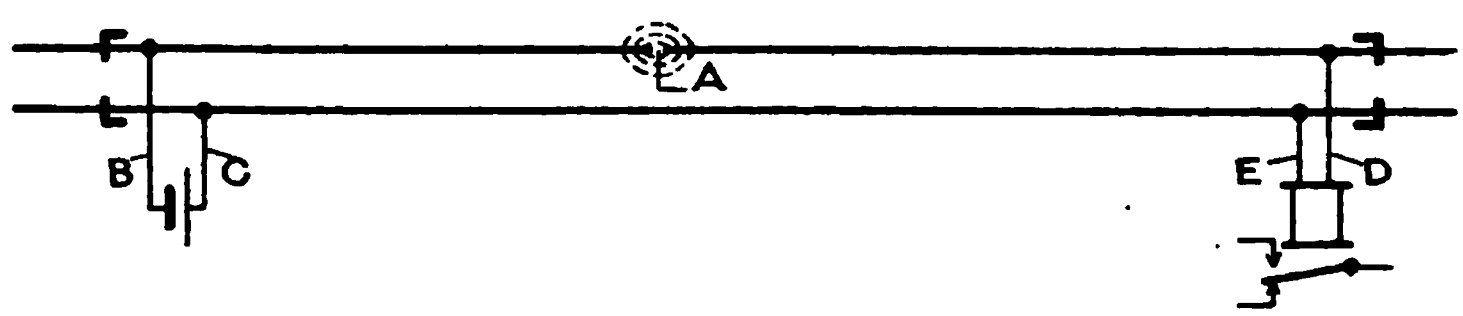

Fig. 84

the removal of a rail length, for instance at point A, Fig. 84, would open the circuit and de-energize the relay, as shown. However, as explained in Art. 111, the insulation between the rails and ballast is seldom very good, and thus a path is provided through the ballast as shown by dotted lines, so that some current continues to flow through the relay, the amount depending upon the leakage around the break. Of course, in any case the more resistance the break inserts into the circuit, the more effective it will be in reducing the amount of current passing through the relay.

In many instances this current will be *below* the drop-away point of the relay, and consequently its armature will be *down*. In other instances the current which continues to flow through the relay, may be *above* the pick-up point and under such conditions. the relay will continue to operate as usual, the broken rail having *no effect* upon it. Again, the current still passing through the relay. may be *between* the drop-away and pick-up points and in such instances the armature will remain raised if there is no train on the circuit. but if shunted the relay will not again pick-up.

It will be noted that the tendency of a broken rail to de-energize the relay will be practically the same if the break occurs in either rail. anywhere between the points at which the *battery leads* B and C, and *relay leads* D and E, are attached to them. It is therefore apparent that these leads must be connected to the rail at the extreme ends of the circuit, keeping as much rail as possible *in series* with the battery and relay. The effect of placing either the battery or the relay at some distance from the end of the circuit, thus connecting part of

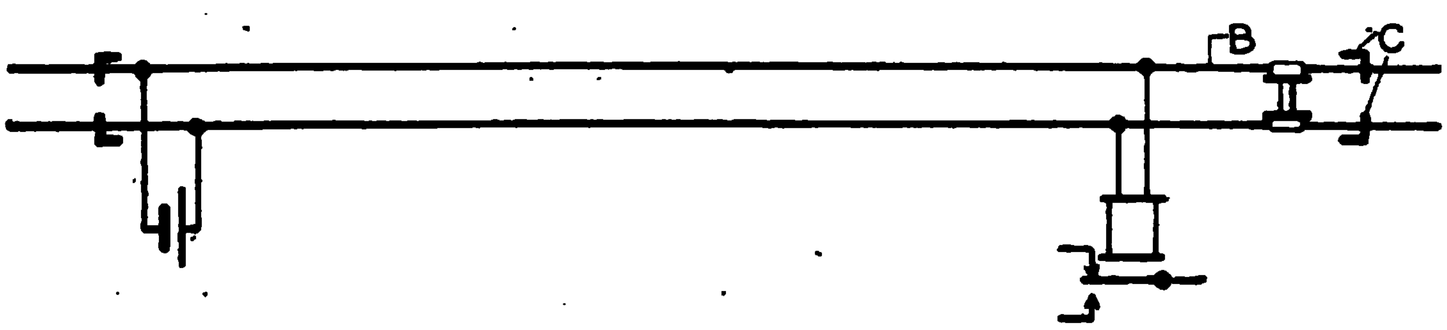

Fig. 85

the track *in multiple,* is illustrated in Fig. 85. It will be observed that with a break in the rail or poor bonding at point B, the relay will not only fail to indicate this fact when the track is unoccupied, but will probably fail to indicate the presence of wheels at any point between the break and joints C.

There is a possibility of a rail breaking close to, or within a joint, between the bond connections and the end of the rail. If such a break should occur, the current would pass around it through the bond wires and continue to energize the relay.

Thus it will be seen that the usefulness of the track circuit for detecting broken rails, or the removal of a portion of the rails, is limited and cannot be considered either complete or reliable under all circumstances.*

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*Broken rail protection is further treated in Arts. 154 and 167.

123. Function: From the foregoing it is apparent that when a track circuit is operating properly, the *relay indicates* by the position of its armature, whether or not the section of track, included within the limits of the circuit is *occupied* by a car or train.

It is evident that any circuit, controlled through a *front* contact on the relay will be *closed* when the track is unoccupied, and *open* when occupied, and, inversely, any circuit controlled through a *back* contact, will be *open* when the track is unoccupied, and *closed* when the track is occupied.

Therefore it may be said that the function of the track circuit is to provide a means for the *automatic control* of signal devices.

124. Defective Conditions: It will be noted that, in this type of track circuit, defective conditions, such as battery failures (from broken jars or otherwise), disconnected or broken wires, poor connections in wiring, crossed wires on account of defective insulation, broken rails, defective bonding or excessively low ballast resistance, tend to produce the same effect upon the relay as the presence of a train. As this indication causes those concerned to suppose that a train is present, such failures are evidently on the side of safety.

125. Single Rail Track Circuits: In the track circuits illustrated in Figs. 82-84, four insulated rail joints are used; that is, *both* rails are insulated at each end of the circuit. This arrangement is sometimes called a **double rail track circuit.**

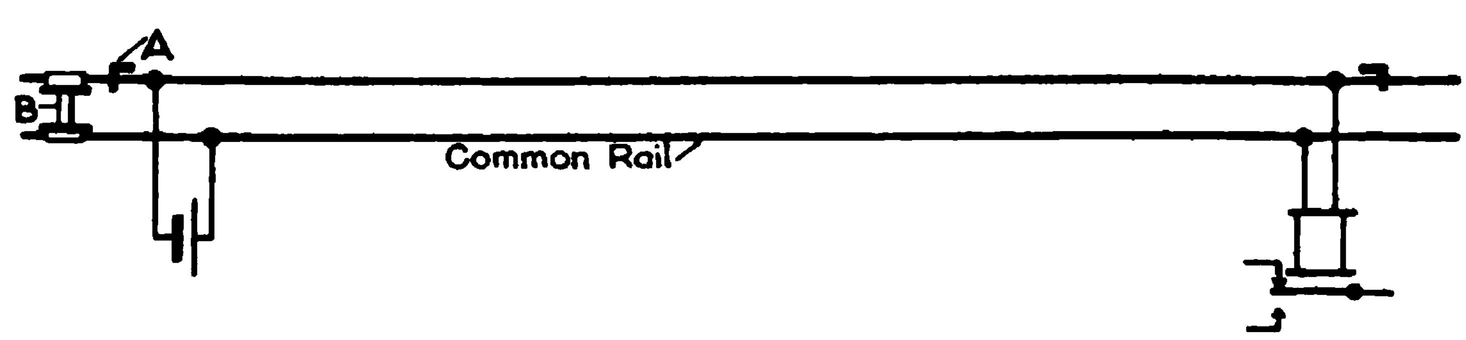

Fig. 86

It will be observed that in Fig. 86, where only *one* rail is insulated, the relay will be operated by the wheels of a train, the same as described in connection with Fig. 83. In other words, if only *one* rail of a track circuit is insulated, the relay will indicate the presence of a train in the same manner as if

both rails were insulated. Such an arrangement is known as a **single rail track circuit.**

The rail in which there are no insulated joints, is generally termed the *common rail,* as it is frequently used as a conductor for other circuits. In the single rail track circuit shown in Fig. 87, it will be noted that the common rail is electrically connected to rails A and B. In this manner the common rail and the rails connected to it often cover considerable area and therefore tend to act as a good ground. Thus a ballast resistance somewhat *lower* than in a double rail circuit is likely to result.

126. If in the single rail track circuit illustrated in Fig. 87, a break should occur in the common rail as shown at point

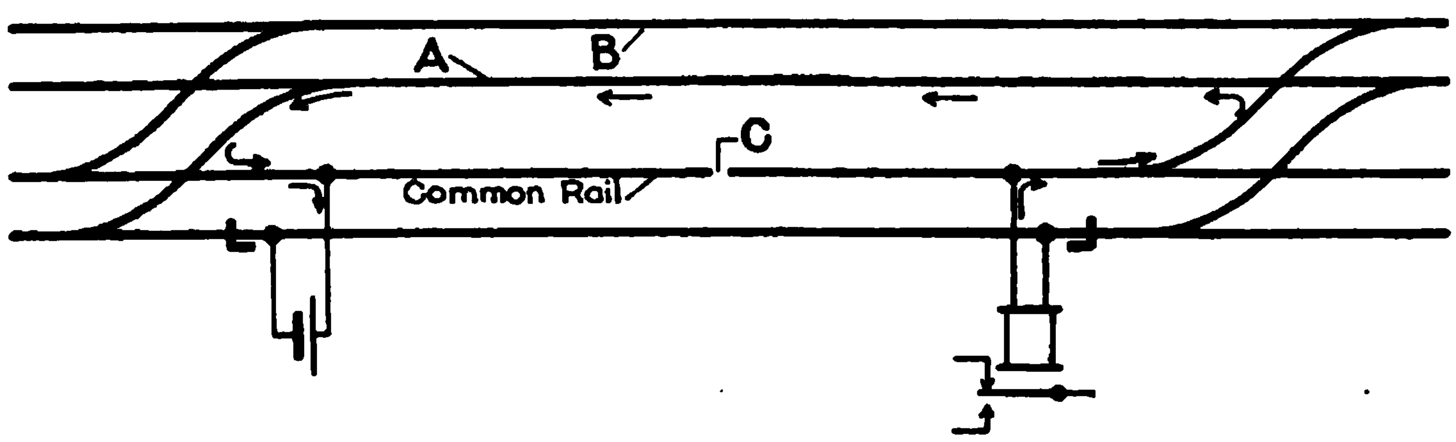

Fig. 87

C, it would be possible for enough current to pass around the break, as indicated by arrows, to still energize the relay. Thus single rail track circuits are not as efficient in detecting broken rails as double rail circuits*.

127. If the insulation should break down in insulated joint A, Fig. 86, it is apparent that the current from the battery would pass through wheels B and would thus be shunted out of the relay improperly; whereas, if both rails were insulated, a breakdown in *two* joints would be necessary to cause such a failure.

SOURCE OF ENERGY

128. Primary Batteries: When primary batteries are used as a source of energy for track circuits, their voltage and in-

*See Art. 417 for other effects of broken rails.

ternal resistance are regulated by the arrangement of the cells. Of course by connecting the cells in series the voltage and internal resistance are *increased,* whereas, by connecting them in multiple, the voltage remains the *same* and the internal resistance is *decreased.* Thus, to secure the best arrangements for various conditions occurring in track circuits, the values E and b, Art. 112, may be varied to a certain extent.

129. With *gravity batteries,* the arrangements of cells shown in Fig. 88 represent various combinations used to accomplish this purpose.

For *short* circuits where the ballast resistance is *high, one* cell, as shown at A, is sometimes used, but this arrangement is somewhat objectionable in that it will become inoperative if the jar is broken.

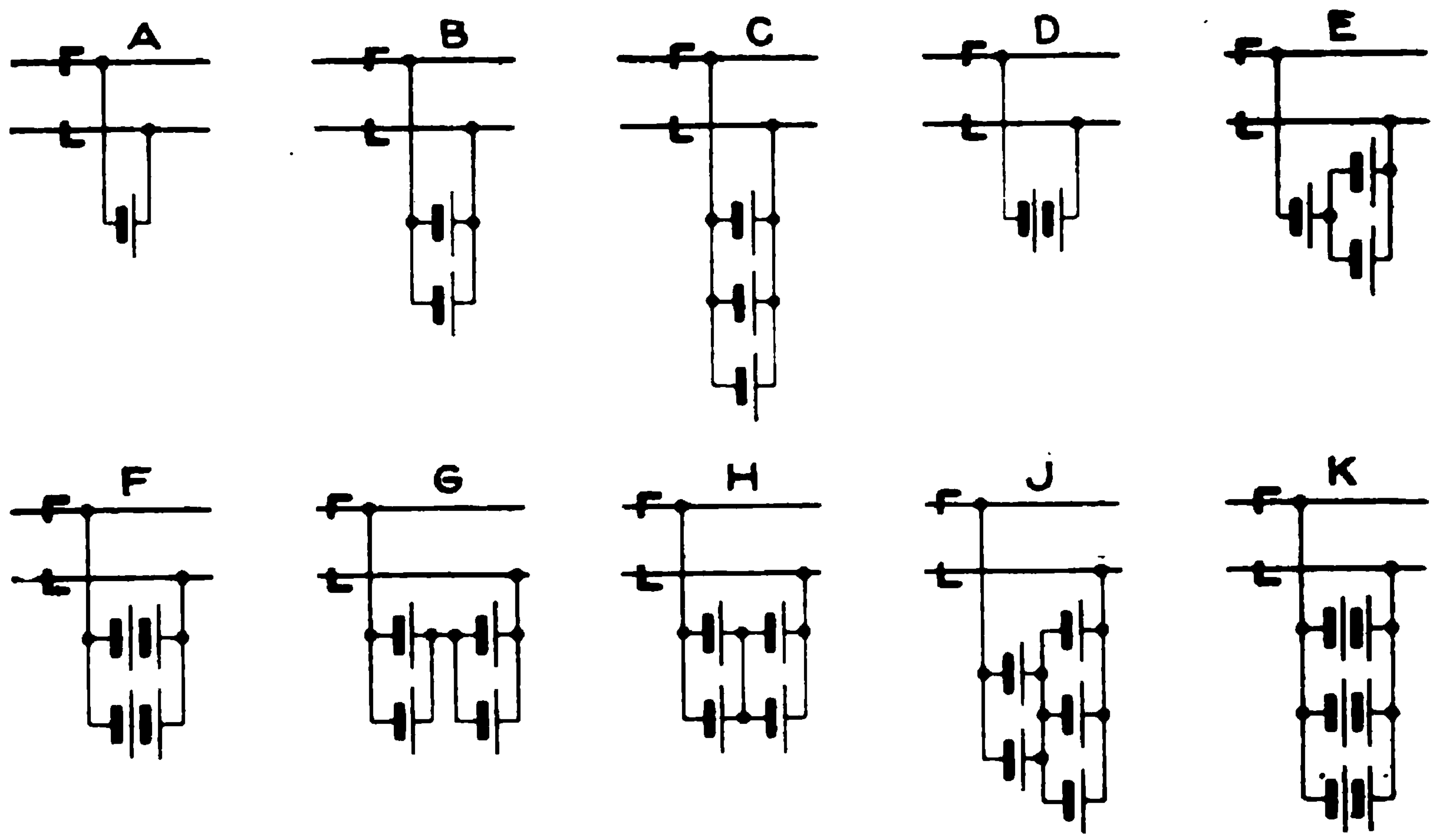

Fig. 88

To overcome this objection, it is customary to use two or more cells connected *in multiple,* so that if one jar is broken, the remainder of the battery will maintain a working voltage until the deranged cell can be repaired.

130. With arrangement B this protection is provided *except,* of course, where, on account of the additional current available, this arrangement is used on track circuits of *lower* ballast resistance, than could be operated by *one* cell. In the latter instance

arrangement C may be used, if it is desired to guard against failure on account of a broken jar.

131. When it is desired to use a higher voltage than is furnished by arrangements A, B or C, arrangement D may be used. Of course with this arrangement the internal resistance of the battery is also *increased* and broken jar protection is not provided.

132. Arrangement E produces the same voltage as arrangement D, but the internal resistance is *lower*. These cells do not exhaust uniformly, and therefore require somewhat closer attention. It is also possible for a broken jar (that is, in the cell connected in series) to cause a failure of the battery.

133. Arrangement F is frequently used on *long* track circuits, with good results.

Arrangement G and H are modifications of arrangement F. The results electrically are the same in all three cases, but in G and H, better service is rendered in case of a broken jar or a broken wire. If a jar should break in arrangement F the battery would be reduced to arrangement D, whereas, with G and H, the same occurrence would result in arrangement E. A break in the single wire connecting the two sets of cells, arrangement G, which would put the entire battery out of service, could not happen with either F or H. The wiring for H when placed in a battery chute is, however, somewhat complicated.

134. Arrangements J and K are seldom used except in extreme cases where the circuits are long and the ballast resistance is very low, such as in tunnels, etc. The *six* cells shown in arrangement K may be considered the maximum gravity battery which it is customary to apply to ordinary track circuit work. In arranging these groups the connections may be varied in the same manner as with arrangement F, in G and H.

135. To calculate the current passing through the relay, when the track is *unoccupied,* for any of these battery arrange-

ments, formula (3) is used. For instance, with two cells of battery, each having an effective E. M. F. of 1 volt and an internal resistance of 2 ohms, arranged as shown at B, and a ballast resistance of .8 ohm, the formula for finding the current through a 4-ohm relay would read;

$$i = \frac{1}{1 + 4 + \frac{1 \times 4}{.8}} = .100 \text{ amp., or } 100 \text{ mil-amp., } \textit{Ans.}$$

If the same two cells were arranged as shown at D the formula would read;

$$i = \frac{2}{4 + 4 + \frac{4 \times 4}{.8}} = .0714 \text{ amp., or } 71.4 \text{ mil-amp., } \textit{Ans.}$$

136. By using this formula, the curves shown in Figs. 89-92 have been plotted for use with normally closed track circuits. The effective E. M. F. of one cell is taken as 1 volt, and the internal resistance of same, 3 ohms. By thus assuming a comparatively low voltage and the maximum internal resistance that is likely to occur, as a basis of calculation, it is apparent that the curves represent the minimum current that will pass through the relay. On this account readings taken in practice will usually be somewhat higher than indicated by the charts. The resistance of the rails and wiring has been disregarded. The ballast resistance is shown at the bottom of the charts, and the current passing through the relay at the side. Each curve is lettered to correspond with the battery arrangement which it represents.

If it is desired to find how much current will pass through a 4-ohm relay, with battery arrangement D, when the ballast resistance is 2.4 ohms; the vertical line from 2.4 at the bottom of Fig. 90, is followed upward until it intersects curve D; the horizontal line from this point is then followed to the left of the chart, where it is found to be marked 100. Therefore a current of 100 mil-amperes will pass through the relay.

The four charts shown, cover the ordinary resistances used in track relays. The curves are carried just above their *working points,* which is that point at which the relays ordinarily operate in good weather. The working point is high enough *above* the

pick-up point of the relay, to insure its proper operation under the most *unfavorable* weather conditions. For instance, the *working point* of a 4-ohm relay is 115 mil-amperes, and the *pick-up point* 65 mil-amperes, thus allowing a drop of 50 mil-

OHMS RESISTANCE FROM RAIL TO RAIL THROUGH TIES AND BALLAST.

Fig. 30

OHMS RESISTANCE FROM RAIL TO RAIL THROUGH TIES AND BALLAST

Fig. 29

amperes, which is considered more than will be produced by the most adverse weather conditions.

The charts are constructed to aid in determining the battery arrangements required for various track circuits.

The tables, in Figs. 89-92, marked ***maximum current through relay*** show the current that would pass through the relay, if there were ***no leakage*** of current through the ties and ballast.

OHMS RESISTANCE FROM RAIL TO RAIL THROUGH TIES AND BALLAST

Fig. 91

Fig. 92

The *pick-up, drop-away* and *working points* given, represent common practice, although these values differ to some extent, in relays of various designs.

137. **Problems.—In the following problems the values for a single cell are effective E. M. F., 1 volt, and internal resistance, 3 ohms.**

(1) In considering the installation of a certain track circuit, its ballast resistance is found to measure 1.2 ohms. (*a*) Using formula (3), find what current will pass through a 4-ohm relay with battery arrangement B? (*b*) What with arrangement F?

(2) The ballast resistance of a certain track averages 8.4 ohms per 1,000 ft. (*a*) Using formula (3), find the current passing through a 9-ohm relay, with battery arrangement B, installed on a 3,000 ft. track circuit? (*b*) What with battery arrangement C?

Check the results obtained in the foregoing problems, by the charts.

Answers.—(1) (*a*) 95.2 mil-amp. (*b*) 117.6 mil-amp. (2) (*a*) 65.3 mil-amp. (*b*) 75.7 mil-amp.

138. Among *other types* of closed circuit primary batteries which are used on track circuits, are *caustic soda* and *caustic potash cells.*

As the internal resistance of these cells is very low, sometimes not more than .025 ohm, the large amount of current that would flow, if they were allowed to be short-circuited by a train, would rapidly exhaust them. Therefore it is desirable to connect an *adjustable resistance* (Arts. 49 and 53) as shown in Fig. 93, *in series* with them which limits the flow of current. The resistance may be placed in either the positive or negative lead from the battery.

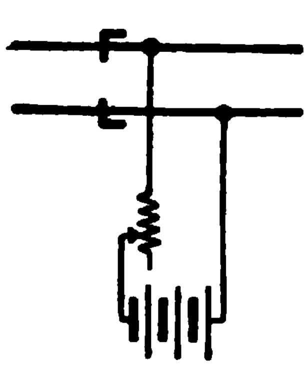

Fig. 93

The effective E. M. F. of this type of battery is lower than that of the gravity cell which, together with their low internal resistance, permits more cells to be placed *in series* with good results. Also on account of their low internal resistance, there is not as much *increase* in current to be obtained by connecting them *in multiple* as with gravity cells. These cells require comparatively little handling, when in service, and thus broken jar protection is not a very important factor.

139. Storage Batteries: The storage battery is well adapted to meet the requirements of track circuits. The voltage of a single cell is much higher than that of the types of primary batteries commonly used for this purpose, and is fairly constant,

for although the range between the maximum and minimum voltage is wide, the actual variation in service may easily be kept within a very small range. This is accomplished by providing cells of such a size that, with the ordinary frequency of charging, they are never required to give more than a small percentage of their actual ampere-hour capacity. This arrangement, on account of the *low rate of discharge,* produces a battery of high capacity and efficiency, and also furnishes a large amount of reserve energy which is always available in case of emergency, such as failure of charging apparatus, etc.

As the internal resistance of the storage cell is extremely low, it is *always* necessary to use artificial resistance,* which is an advantage, in that it is free from the variations occurring in the internal resistance of primary cells, and furthermore it can be adjusted to the requirements of each circuit.

140. Ordinary practice followed in the use of storage batteries on track circuits may be divided into two general methods, as follows: first, where a separate battery is provided for each circuit, and second, where one battery supplies current to a number of circuits.

141. The first method resembles in many respects the arrangements already described for primary batteries. The resistance may all be placed in one lead as illustrated in Fig. 94, but it is often divided, part being placed in each lead as shown in Fig. 95. The object of this latter arrangement is to protect the battery in case one of the resistances should become *bridged,*** or if one side should become *grounded* close to the battery terminal. For instance, the wiring shown in Fig. 94 might become grounded at point A, and as the rails form quite a good ground in wet weather, the large amount of current which would flow through the paths indicated by the dotted lines, might result in quickly *exhausting*

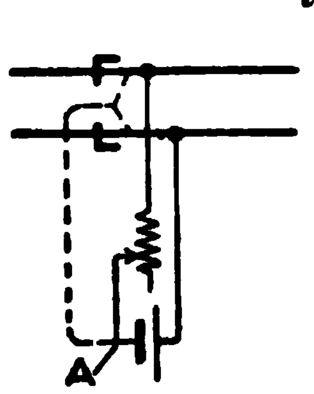

Fig. 94

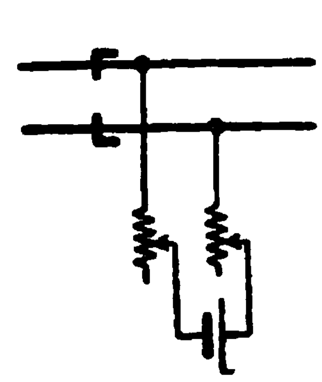

Fig. 95

*For effect of short circuit on storage batteries see **Magnetism and Electricity.**
**Shunted.

the battery, or injuring it by a *high* rate of discharge. The combined resistance of these paths would be still lower during the presence of a train on the circuit. On the other hand, if the wiring shown in Fig. 95 should become grounded near *either* terminal of the battery, the resistance in the other lead would still be effective to prevent a short circuit,

As the average effective E. M. F. of a storage cell is about 2 volts, they are seldom connected *in series*, for use on a single circuit, but two cells may be connected in multiple if it is desired to guard against failure on account of a broken jar, in which case smaller size cells may be used. However, as the cells are subject to very little handling, broken jar protection is considered an unimportant factor.

142. The second method is used when there are a *number* of track circuits so situated that they may be supplied from the same point. Such instances occur at interlocking plants, where a number of short track circuits are often required.

143. One arrangement for such circuits is shown in Fig. 96, in which single rail track circuits are used. The adjustable resistances are inserted in the leads between the main battery wire and the insulated rail of each circuit. The common rail of all circuits is connected to the other main lead from the battery. It is customary in such installations to place two fuses, one in each main battery wire as shown, to protect the battery in case of a short circuit or a ground, in the wiring. In this connection it should be noted that the blowing of a fuse will put all circuits out of service, and that on account of the larger territory covered by the common rail, a ground at point B, is likely to have a greater short circuiting effect than with the arrangement shown in Fig. 94.

Fig. 96

144. In order to guard against such failures the arrangement

shown in Fig 97 is frequently used. With this arrangement double rail track circuits are employed and adjustable resistances are placed in each of the leads from the main battery wires to the track. Thus the advantages described in connection with Fig. 95 are secured.

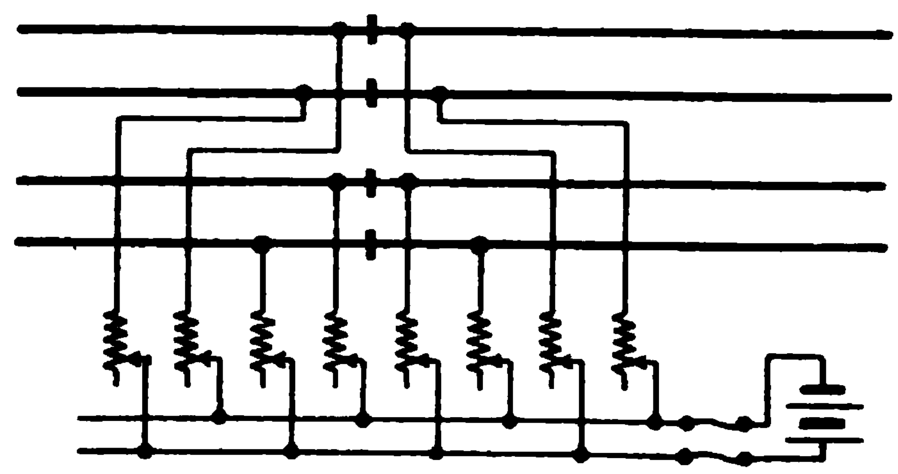

Fig. 97

145. The employment of storage batteries to feed a number of track circuits in multiple is limited to circuits under 1,000 ft. in length, owing to the probability of trouble from *foreign currents.** On circuits of greater length, it is considered desirable to provide a *separate* source of energy for each circuit.

146. On account of the low internal resistance of storage cells and consequently the comparatively high current output available, *one* cell (80 ampere-hour) can be used to advantage to feed *two* or *three* track circuits. In such cases *two* ohms resistance would be inserted in each circuit,** (one ohm in each lead). Where a *larger* number of circuits are to be supplied from the same battery, it is customary to place two or more cells in series, thus providing a higher voltage, which necessitates an increase in the artificial resistance.

147. A distinctive gain in effective shunting is provided with the high voltage, high resistance, arrangement; that is, the possibility of sufficient current still passing through the relay to *hold up* its armature, on account of *poor contact* between the wheels and rails, is *greatly reduced.*

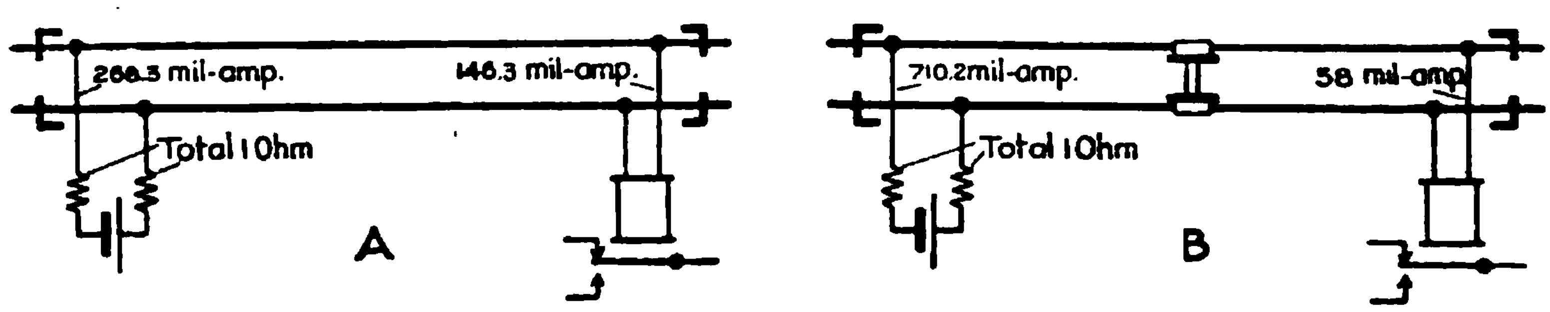

Fig. 98

*See Art. 484.
**Disregarding the internal resistance of the storage cell, this arrangement corresponds to that represented by curve K, Figs. 89-92.

This is illustrated by Figs. 98-99 in which Fig. 98 shows a track circuit operated by an effective E. M. F. of 1 volt, through a resistance (either internal or artificial) of 1 ohm, and Fig. 99, a track circuit operated by an effective E. M. F. of 12 volts, through a resistance of 42 ohms. In each of the circuits, a

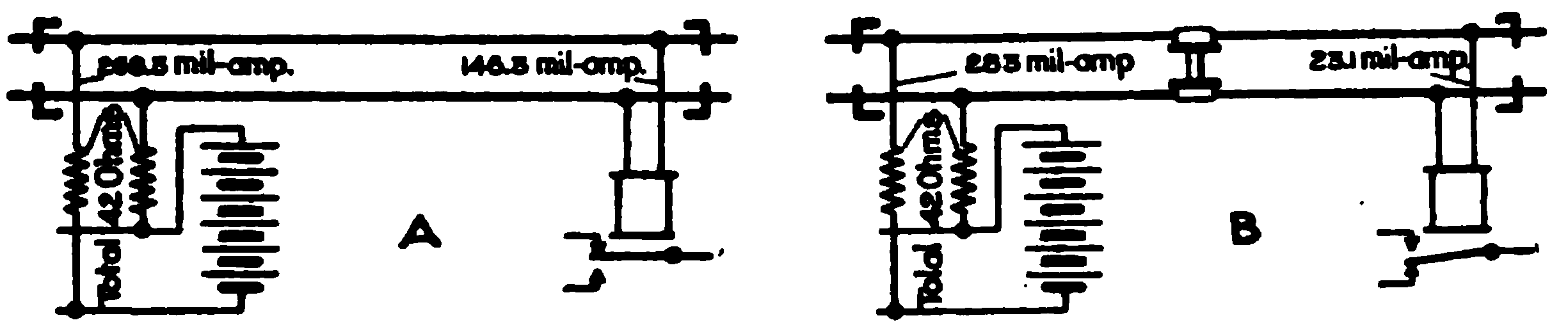

Fig. 99

5-ohm relay (pick-up point 55 mil-amperes and drop-away point 25 mil-amperes) is used, and the ballast resistance is assumed to be 6 ohms.

148. When the track is unoccupied, as shown by sketches A, it will be noted that the current output from both batteries is the same, and consequently the current through the relays is the same; that is, the current output is 268.3 mil-amperes and the current through the relays 146.3 mil-amperes.

Sketches B show the same circuits, the track being occupied by wheels, which, it is assumed, make an unusually *poor contact* with the rails, the resistance from rail to rail through them, being .48 ohm.

149. The following are calculations of the *resistances, current output from the batteries,* and *current through the relays,* when the track is unoccupied and occupied.

Resistance calculations for Figs. 98-99.

Fig. 98-A

2.727 ohms = joint resistance of ballast and relay.
1.0 ohm = artificial or internal resistance at battery.

3.727 ohms = total resistance of circuit with track *unoccupied.*

Fig. 98-B

.408 ohms = joint resistance of ballast, relay and shunt (wheels).
1.0 ohm = artificial or internal resistance at battery.

1.408 ohms = total resistance of circuit with track *occupied.*

Fig. 99-A

2.727 ohms = joint resistance of ballast and relay.
42.0 ohms = artificial or internal resistance at battery.

44.727 ohms = total resistance of circuit with track *unoccupied.*

Fig. 99-B

.408 ohms = joint resistance of ballast, relay and shunt.
42.0 ohms = artificial or internal resistance at battery.

42.408 ohms = total resistance of circuit with track *occupied.*

150. It will be noted that the ratio between the total resistances in sketches A and B, Fig. 98, is much greater than between the total resistances in sketches A and B, Fig. 99. In other words, the presence on the track circuit of wheels making poor contact, causes the total resistance in Fig. 98 to vary in the ratio of 1.408 to 3.727, whereas in Fig. 99, the total resistance varies in the ratio of 42.408 to 44.727.

151. The following current calculations indicate the effect of these resistance variations, on the current output from the batteries and the current through the relays.

Current calculations for Figs. 98-99.

Using *Ohm's Law* in which I = current output from battery, E = effective E. M. F., and R = total resistance of circuit, to

find current output from battery; and formulas (3) and (6) to find current through relay, we obtain,

	Current output from battery.	Current through relay.
Fig. 98-A	$I=\frac{E}{R}=\frac{1}{3.727}=.2683$ amp. or 268.3 mil-amp., *Ans.*	146.3 mil-amp.
Fig. 98-B	$I=\frac{E}{R}=\frac{1}{1.408}=.7102$ amp. or 710.2 mil-amp., *Ans.*	58 mil-amp.
Fig. 99-A	$I=\frac{E}{R}=\frac{12}{44.727}=.2683$ amp. or 268.3 mil-amp., *Ans.*	146.3 mil-amp.
Fig. 99-B	$I=\frac{E}{R}=\frac{12}{42.408}=.283$ amp. or 283 mil-amp., *Ans.*	23.1 mil-amp.

152. With the 1 volt battery, the current, 58 mil-amperes, flowing through the relay, after the car wheels have passed onto the circuit, is not only *above* the *drop-away* point, consequently holding the armature up, but also *above* the *pick-up* point, so that if the relay should be disconnected, thus causing the armature to drop, and then be again connected, the armature would pick-up. Thus on account of the exceptionally high resistance of the path through the wheels, the relay gives a *false* indication that the track is unoccupied.

On the other hand, with the 12 volt battery, the current 23.1 mil-amperes, flowing through the relay, after the car wheels have passed onto the circuit, is *below* the *drop-away* point, and consequently the armature drops, thus giving the proper indication.

153. It should be noted that considerably more energy is consumed with the high voltage arrangement; for instance, when the track is unoccupied the watt output from the battery in Fig. 98-A, is $W = E \times I$ or $W = 1 \times .268 = .268$ watt; whereas, with Fig. 99-A the watt output is $W = E \times I$ or $W = 12 \times .268 = 3.216$ watts, which is just 12 times as much energy expended as with the low voltage arrangement. When the battery is shunted by a pair of wheels making *good contact* with the rails, the high voltage battery still consumes 3 to

4 times as much energy as the low voltage battery. However, this difference in consumption of energy is not a very important factor, as with any arrangement, a comparatively small amount of energy is consumed. Also, as the artificial resistance in the high voltage arrangement, constitutes the greater part of the total resistance of the circuit, there is some advantage gained, in that there is less variation in the current output from the battery; that is, the presence of a train does not cause as great a percentage of increase in the current output, that it does with the low voltage arrangement.

154. While the raising of the battery voltage and artificial resistance tends to produce a safer condition as regards the shunting of the relay, it produces the opposite effect upon the efficiency of the track circuit in detecting broken rails. For example, in Figs. 98-99, if the ballast resistance should be increased to such an extent that it approached perfect insulation, and could thus be omitted from the calculations, the current through the relay, with the 1-volt arrangement, when the track is unoccupied, would be 166.7 mil-amperes, and with the 12-volt arrangement, 255.3 mil-amperes. If now a resistance of 78 ohms should be inserted as the result of a broken rail, the current through the relay with the 1-volt arrangement would be 11.9 mil-amperes, while with the 12-volt arrangement it would be 96 mil-amperes. While the presence of the path through the ties and ballast serves to modify these figures considerably, still the tendency toward failure to detect a broken rail is always greater with the higher voltage arrangement.

155. To accomplish the best results both in economy of operation and safety in shunting, after the voltage of the battery has been determined, the artificial resistance should be adjusted as high as possible. To do this, the ballast resistance must be measured, or estimated, under the most *unfavorable* conditions that are likely to occur in operation (maximum leakage from rail to rail). Using the figure thus obtained as the value of n, formula (3) may be used, arranged as follows;

$$b = \frac{En - inr}{in + ir}. \qquad (7)$$

In this case, i represents the pick-up current of the relay plus any percentage that it may be desired to allow as a *working margin,* to insure the proper operation of the relay.

Now assuming, for example, that the battery is arranged to give an effective E. M. F. of 8 volts, that the minimum ballast resistance is estimated to be .7 ohm, and that a 9-ohm relay is used, whose pick-up current is 40 mil-amperes, above which a working margin of 10% is to be allowed, the formula will read;

$$b = \frac{(8 \times .7) - (.044 \times .7 \times 9)}{(.044 \times .7) + (.044 \times 9)} = 12.5 \text{ ohms, } \textit{Ans.}$$

Therefore, under the given conditions, a resistance of 12.5 ohms would insure a flow of current through the relay, 10% above its pick-up point, with the most *unfavorable* ballast resistance.

156. **Problem.—On a certain track circuit the minimum ballast resistance is estimated to be .8 ohm. What artificial resistance will it be necessary to insert in series with a 10-volt storage battery, to insure a 20% working margin for a 12-ohm relay, having a pick-up point of 36 mil-amperes?**

Answer.—13.7 ohms.

157. Another reason for keeping the artificial resistance as high as circumstances will permit, is to prevent a large amount of current flowing through the relay when the ballast resistance is high. A large amount of current through the coils of the relay tends to increase the residual magnetism in the cores of the relay, and thus lower its drop-away point.

158. In some cases it is convenient to use current for track circuits, from a battery which is also used on *other circuits.* A storage battery of 20 volts or less is often available especially at power interlocking plants, and with suitable resistance (sometimes as high as 140 ohms) in each circuit, may be used to supply 20 or 30 short track circuits. By so doing the arrangements for charging the cells is much less complicated than could be provided in any other way; and, of course, this arrangement is very favorable to the effective shunting of the relay in case of

poor wheel contact. Either single or double rail circuits may be used in such cases.

159. The artificial resistances used when the same battery supplies current to both track and line circuits, are sometimes made in the form of coils having soft iron cores, as mentioned in Art. 54. These are designed to act as choke coils to prevent the passage of lightning discharges between the track and the line circuits.

160. Generators: Where current from a generator is available, it may be applied *directly* to the track, and when thus arranged makes a very satisfactory source of energy. With suitable regulating apparatus, the voltage may be maintained practically constant, or altered as desired, to meet variations in ballast resistance.

161. Fig. 100 illustrates such an arrangement, using single rail track circuits, this being designed for an electrified road (Boston Elevated Ry.) where the common rail acts as a return

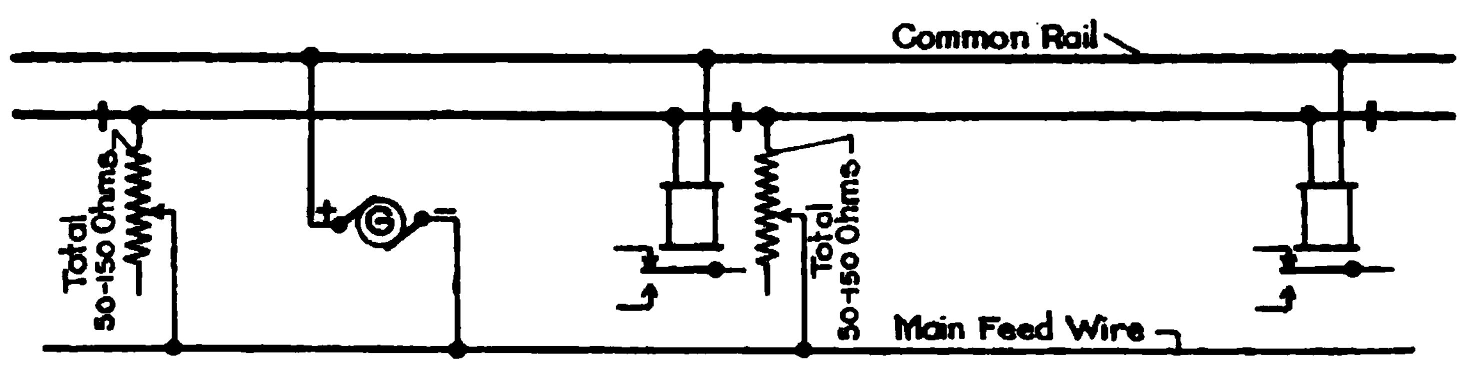

Fig. 100

for both the track circuits and the propulsion current. As indicated, one terminal of the generator is connected to the main feed wire for the signal system and the other to the common rail. The adjustable resistance, placed in the lead between the main feed wire and the insulated rail of each track circuit, may be varied from 50 to 150 ohms. The effective E. M. F. of the generator is regulated according to weather conditions, between 90 and 110 volts. Thus, while there is always available an ample supply of current to provide for the worst possible weather conditions, the relays are not subjected to an undesirable amount in good weather.

The relay used is specially designed to avoid interference from propulsion current. Its construction includes a resistance of 50 ohms, with a pick-up point of 100 mil-amperes and a drop-away point only a small percentage below the pick-up point.

162. The arrangement shown in Fig. 101 represents a method used to supply current to track circuits from the third rail of

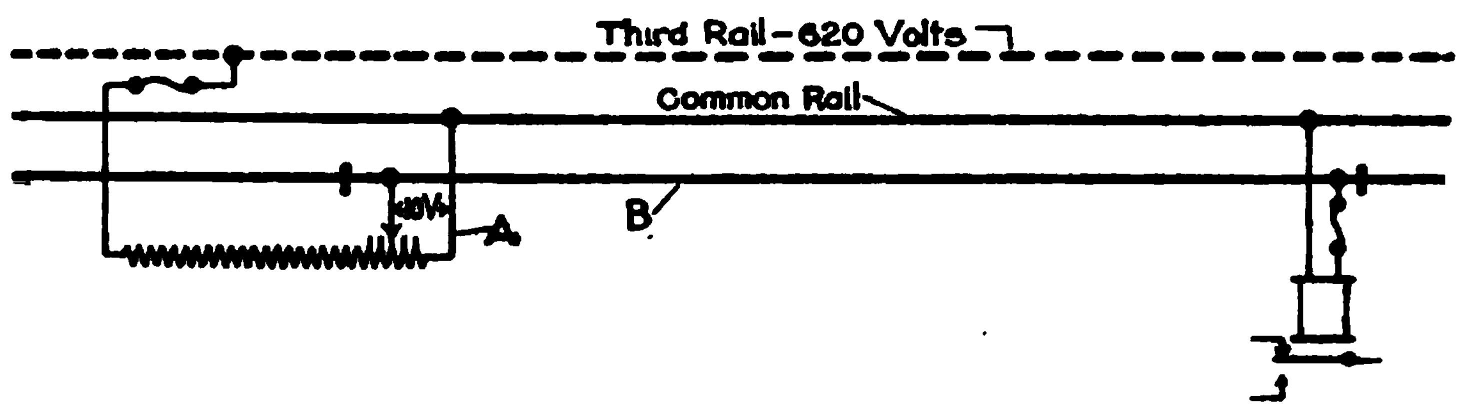

Fig. 101

an electrified road. This is also a single rail arrangement with return propulsion current passing along the common rail. The potential on the third rail is 620 volts. Current from this source is taken through a 3-ampere fuse and then through a resistance plate containing a total of 425 ohms, with five taps 5 ohms apart at one end. Two leads having a difference of about 10 volts potential between them are taken from these taps; the one from the end of the plate is connected to the common rail and the other to the insulated rail.

The relay which is protected by a 3-ampere fuse, is wound to a resistance of 50 ohms and has a pick-up point of 80 mil-amperes with a drop-away point of 60 mil-amperes.

The purpose of lead A from the end of the resistance plate to the common rail is to avoid an excessive voltage between the rails in case the fuse at the relay should be blown. For instance, if lead A should be removed and the relay fuse blown, the voltage between the running rails would increase according to the ballast resistance, which if high, would maintain a dangerous potential between the rails.

NOTE.—While D. C. Track circuits are used to some extent on roads using electric propulsion, A. C. track circuits are generally employed.

163. Where current from commercial power mains is obtain-

able it can be utilized to advantage by employing a motor-generator, to change to the required voltage.

The arrangement, described in Art. 158, for supplying both track and line circuits, may be furnished with current in this manner.

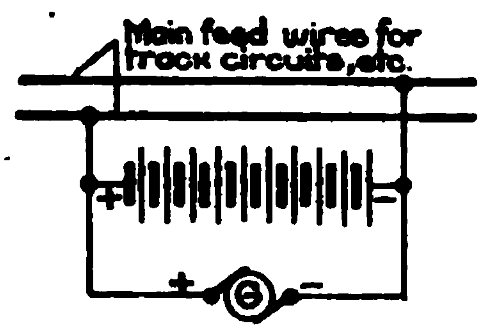

Fig. 102

164. There are in service a number of installations in which a storage battery is connected across the circuit,* as shown in Fig. 102. With such arrangements the battery constitutes a reserve source of energy, in case it should become necessary to shut down the generator, and also provides closer regulation of the load.

RELAYS

165. By comparing the charts, Figs. 89-92, it will be observed that, as the ballast resistance decreases, the relay which has the *lowest* resistance (3½ ohms) is the *last* to become inoperative. It might be inferred from this that, by making the resistance of the relay still lower, it would be possible for it to operate with the ballast resistance still further reduced. This might be done if it were not necessary to provide a margin of safety to insure the release of the armature when the relay is shunted by the wheels of a train. In other words, if the battery voltage and series resistance (internal or artificial) remain the same, the *lower* the resistance of the relay, the more current it will receive and consequently, the more likely it will be to fail to release properly, on account of poor wheel contact. As such a failure would produce a dangerous condition, it is very desirable to keep the resistance of the relay high enough to provide a large factor of safety in this respect. On this account it is usually considered undesirable to use a relay of less than 3½ ohms resistance, although in some extreme cases they have been wound as low as 2 ohms.

*Commonly termed *floated.*

As may be inferred from the foregoing, by increasing the resistance of the relay, although the probability of its failure to pick up on account of *low* ballast resistance is *increased*, its ability to release with a *poor shunt* is also *increased.*

As an occasional failure to pick up is a far less serious occurrence than a failure to release properly, it is much safer as regards shunting, to have the resistance of the relay *too high* than *too low.*

166. Relays wound to 3½ ohms are used on very long, wet track circuits, and at other points where the ballast resistance is very low. The resistance which has been adopted as standard by the R. S. A.* for track relays is 4 ohms. 5-ohm relays are used to a considerable extent, being the standard on some roads. On short track circuits, especially where there is considerable sand used on the track, relays of 9 ohms resistance are frequently used, and occasionally their resistance has been increased to 16 ohms with good results.

On electrified roads where it is necessary to guard against interference from propulsion current, which employs one of the running rails for return from the car motors, it is customary, as stated in Arts. 161-162, to use relays wound as high as 50 ohms.

167. The efficiency of a track circuit to detect a broken rail depends, to a certain extent, upon the resistance of the relay. When two resistances, one fixed and the other variable, as A and B, Fig. 103, are connected in series with a certain source of current, the *lower* the fixed resistance A, the *greater* will be the variation of current passing through it with a given change in the variable resistance B.**

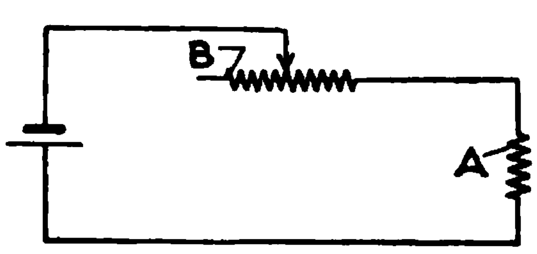

Fig. 103

In a track circuit, the relay represents resistance A, the other resistances in series with it, such as the internal resistance of the battery, resistance of the wiring, rails, etc., being represented by resistance B. Thus, the *lower*

*Railway Signal Association.

See **Magnetism and Electricity.

the resistance of the relay, the *greater* will be the tendency of its armature to drop on account of any increase in the resistance of the circuit, such as would be caused by a broken rail.

By comparing the foregoing conclusion with that in Art. 165 concerning the shunting of the relay, it will be seen that the results as to the safety of operation are *directly opposite*, the *high* resistance relay being safer in regard to releasing when shunted, and the *low* resistance relay, safer in regard to broken rail protection.

Thus, in the resistance of the relay, as well as in the arrangement of battery voltage and artificial resistance (Art. 154), the arrangement which favors the effective shunting of the relay, tends to lessen the efficiency of the circuit to detect broken rails.

RELAYED TRACK CIRCUITS

168. As the resistance of the ballast, at times runs very low, it is evident that with the most favorable relay the length of a track circuit is limited to a few thousand feet, owing, of course, to the fact that the excessive leakage would prevent the relay from receiving enough current to operate it. (The practical maximum length for D. C. track circuits has been found to be from 6,000 to 7,000 ft.).

169. It is often desirable to extend the control of signal apparatus over a greater length of track than this, and in order to do so without the use of line wires, it has been found convenient to use the method illustrated in Figs. 104-106. This arrangement is termed a **relayed track circuit or cut section.**

The arrangement consists of two adjacent track circuits in which the relay of one controls the flow of current from the battery of the other. When a train occupies circuit A, Fig. 105, relay A is shunted in the ordinary manner. When the train occupies circuit B, Fig. 106, relay B, which is then shunted, opens the circuit of battery A, which is the source of energy for circuit A. Thus relay A will be de-energized* when the train occupies either circuit, and any circuit controlled through contacts on this relay will be governed by both circuits.

It will be observed that relay B not only opens the circuit of battery A, but also, through its back contact, closes a shunt on

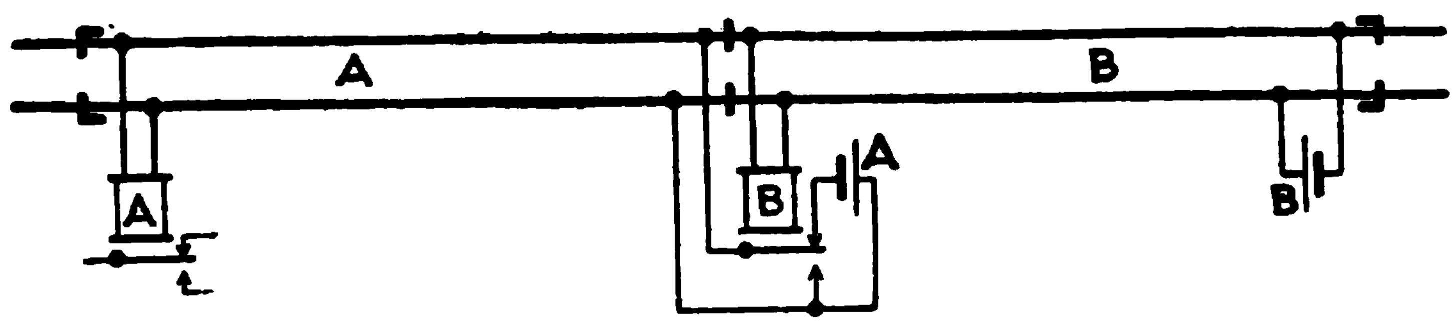

Fig. 104

the rails of circuit A in the same manner as would be done by the wheels of a train. The object of this arrangement is to pro-

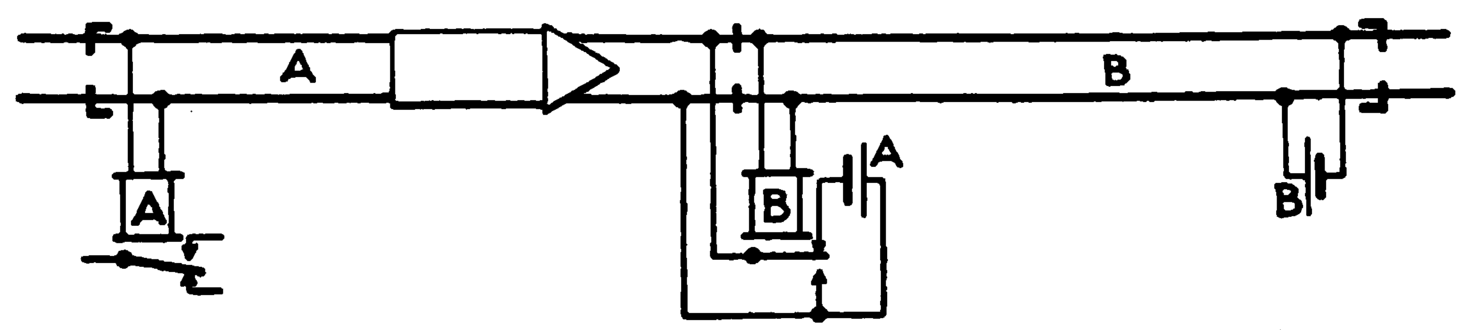

Fig. 105

vide a low resistance path between the rails and thus prevent relay A from being energized by foreign current.

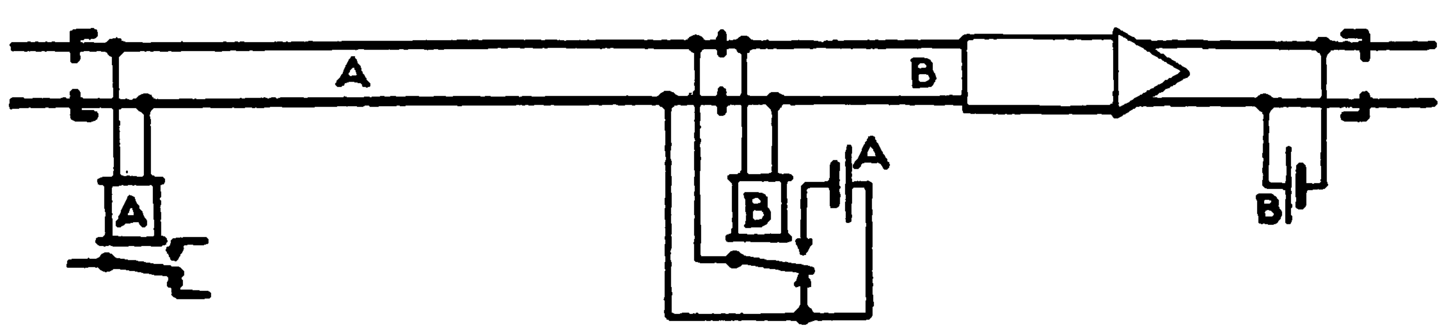

Fig. 106

As the controlled circuits are carried through contacts on relay A, the results will be practically the same,** with the train moving in either direction.

170. By controlling the circuit battery of B, Fig. 107, through contacts on relay C as shown, it will be seen that relays A and B will be de-energized when circuit C is occupied by a train. Thus

*Although, as has been explained, the current is not entirely removed from the coils of the relay when it is shunted in the ordinary manner, by the wheels of a train, it is customary to consider them as being *de-energized*, the amount of current still passing through them being negligable.

There are certain conditions in connection with **Block Signaling that make it desirable to feed *with traffic* rather than against it.

by duplicating the relaying connections between circuits A and B,

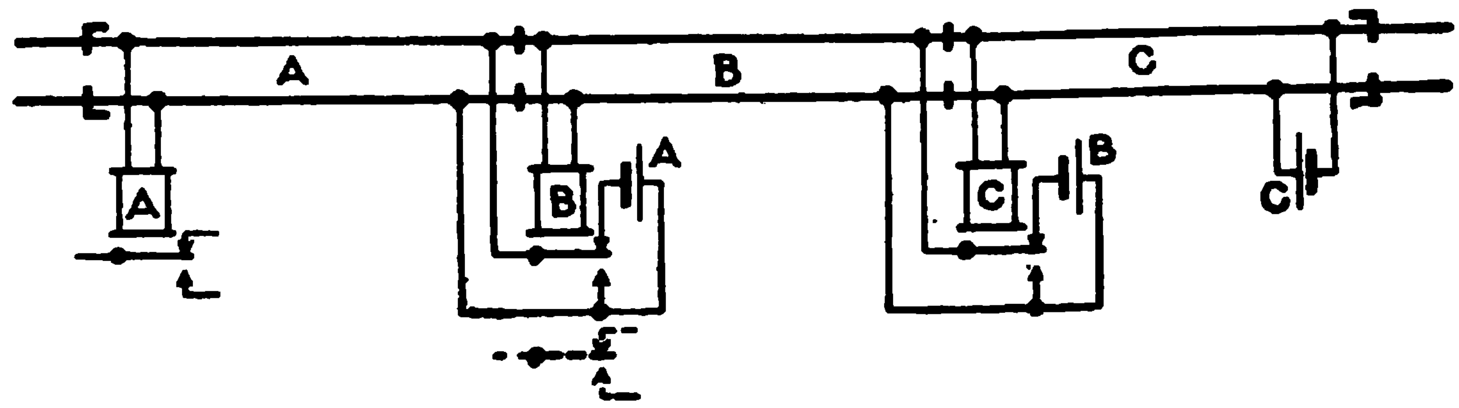

Fig. 107

Figs. 104-106, any desired number of track circuits may be made to produce the same effect as a single circuit.

171. By controlling a circuit through a contact, as shown dotted on relay B, Fig. 107, it will indicate the presence of a train on circuits B and C, but not on A. In addition to the signal apparatus which is controlled through the entire circuit, devices are, in this manner, frequently controlled through *part* of a relayed track circuit.

POLARIZED TRACK CIRCUITS

172. In order to avoid the use of line wires, it is often convenient to arrange track circuits in such a manner that the *polarity* or *direction* of the current, as well as its *presence* in the relay, may be made use of in controlling signal apparatus.

173. In the track circuits which have been described, the polarity of the current has not been considered, the relay operating in the same manner with the current flowing in either

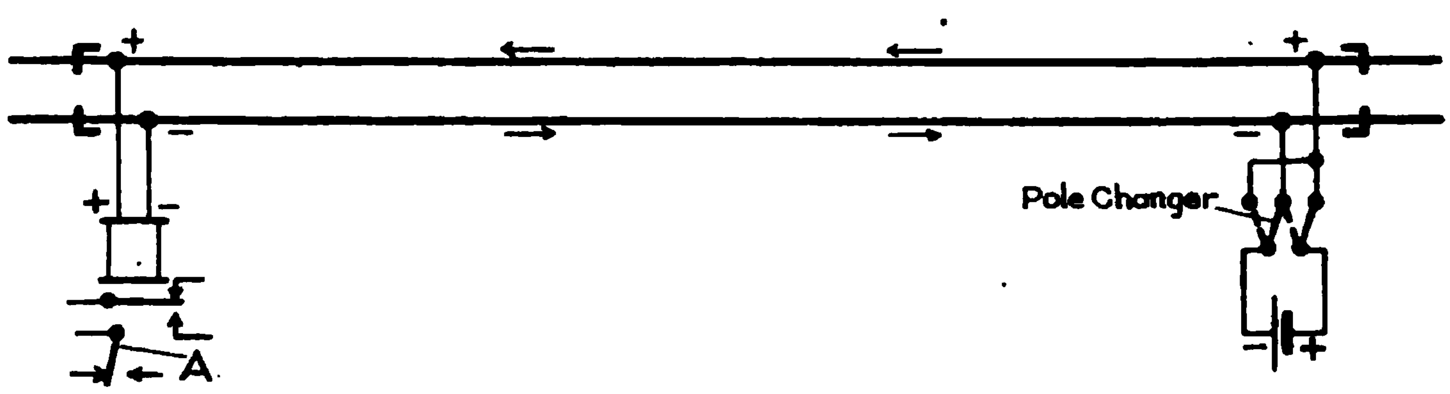

Fig. 108

direction. However, if a *polarized relay* is substituted for the *neutral relay*, and a *pole changer* inserted in the leads between

the battery and the track, as shown in Figs. 108-109,* the position

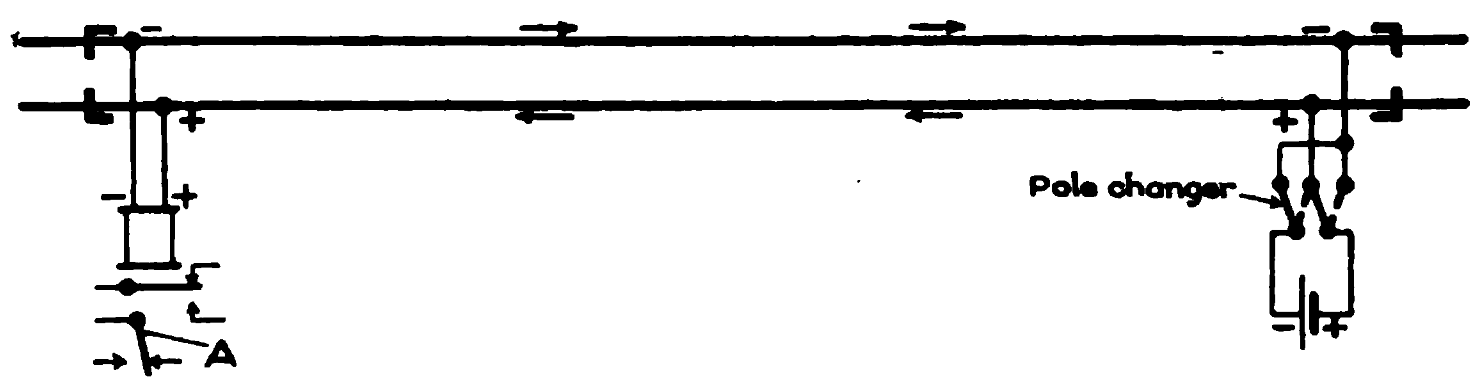

Fig. 109

of the polarized armature, while the circuit is unoccupied, will be governed by the position of the pole changer.

174. In Fig. 108, the current flows in the direction indicated by the arrows, causing the polarized armature A to be deflected to the *left*, as shown. In Fig. 109, the pole changer is *reversed*, causing the current to flow through the relay in the *opposite direction*, deflecting its polarized armature to the *right*. Thus, by operating the pole changer, the polarized armature may be made to assume either position, and any circuit controlled through contacts operated by the polarized armature will be open or closed, according to the position of the pole changer.

175. It will be observed that in both cases, Figs. 108-109, the *neutral armature* of the relay is raised against the front contact, therefore the operation of any circuit controlled through the *neutral contacts* will be the same with the pole changer in *either* position.

176. By arranging the pole changer so that it will be operated by a movable part of any signal device, the polarized armature of the relay may be made to assume a position to correspond with that of the part to which the pole changer is attached. For instance, if the pole changer is attached to a signal arm, so that when the arm is in the *proceed* position, the pole changer will be held as shown in Fig. 108, and when in the *stop* position, it will be held as shown in Fig. 109, the polarized

*The pole changer shown is a mechanically operated circuit controller. The two arms are pivoted at the lower end. and joined by an insulated bar (not shown) so that they remain parallel, the upper ends being moved from one position to the other, thus *reversing* the polarity of the current in the rails. Pole changers are treated more fully later.

armature of the relay will be operated when the signal arm is changed from one position to the other, and any circuits controlled through the polarized contacts on the relay, will be *open* or *closed* according to whether the signal arm is in the *proceed* or *stop* position.

177. As the presence of current in the relay is necessary to reverse the position of the polarized armature, it is evident that this operation can *only* be performed when the track is *not occupied* by a train, because if there were a train on the circuit making good wheel contact, there would not be enough current passing through the relay to operate the polarized armature. Therefore, while there is a train on the circuit, the polarized armature *will not* be reversed, by a reversal of the pole changer. Consequently, the application of the polarized feature of the track circuit is limited to arrangements in which the reversal of the polarized armature is not required during the presence of a train on the circuit.

178. As in most types of polarized relays, the polarized armature does not indicate by its position, whether or not the relay is energized*, the controlling circuits for devices which are to be governed by the presence of a train, must be carried through the *neutral contacts* of the relay.

179. The pole changer is so constructed that it will change from one position to the other *quickly*, thus leaving the relay de-energized but a very short period of time while the direction of the current is being reversed. But as the magnetic flux in the cores and *neutral* armature in one direction must entirely cease before it becomes effective in the other, it is apparent that there must be a moment when there is no attraction between them, and the neutral armature will then be allowed to drop, although it will at once be attracted again, perhaps before it has reached the back contacts.

By the use of *sliding front contacts* on the *neutral armature,* this tendency to open during the change, is to some extent overcome, but in order to obtain the best results it is usually

*See **Relays.**

desirable to provide the instruments, controlled through these contacts, with a *slow-release** which will retain them in position while their circuit is momentarily opened.

180. Relayed Polarized Track Circuits: Polarized track circuits may be relayed in a manner similar to that described in Arts. 168-171 for neutral track circuits.

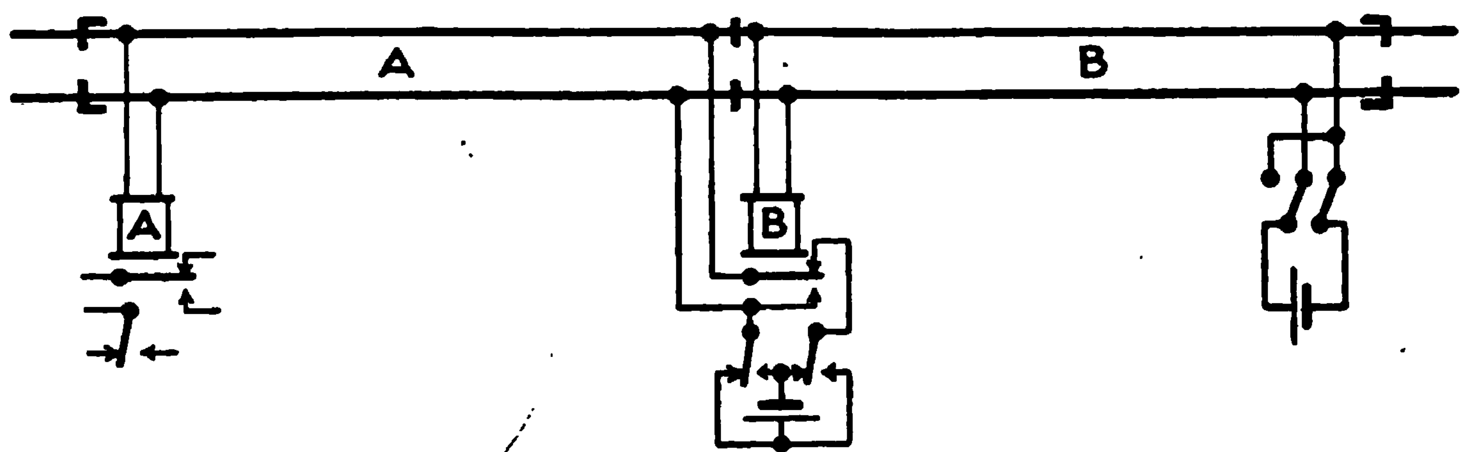

Fig. 110

Such an arrangement is illustrated in Figs. 110-112. The polarized armature of relay B, which operates a double set of contacts, acts as a pole changer for circuit A. Thus, when the

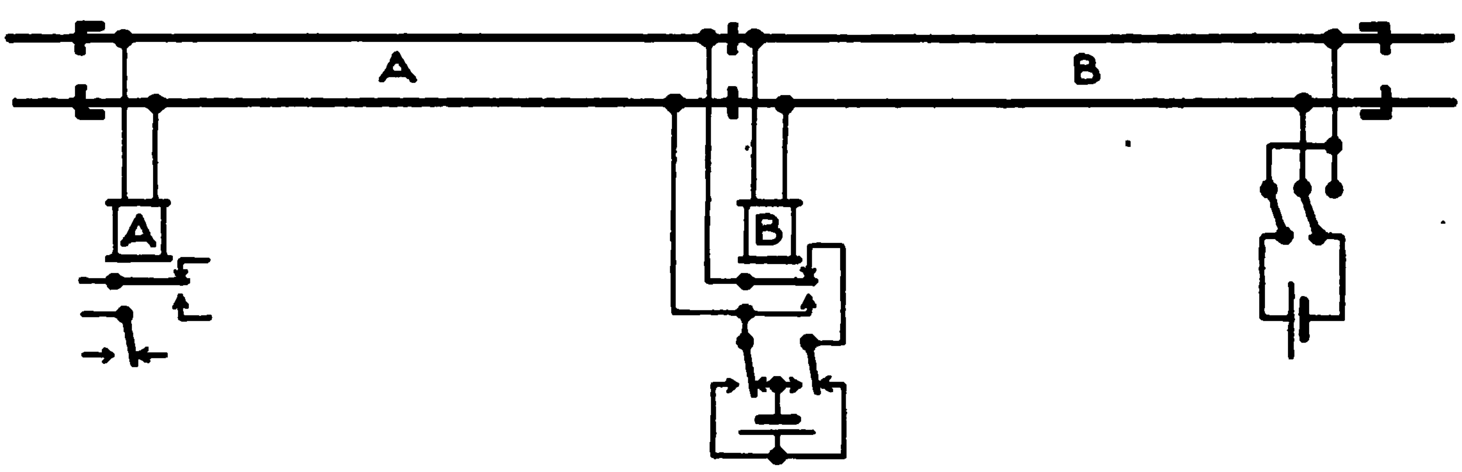

Fig. 111

pole changer is reversed, the polarized armature of relay B is reversed, which in turn reverses the polarity of circuit A, and consequently the polarized armature of relay A.

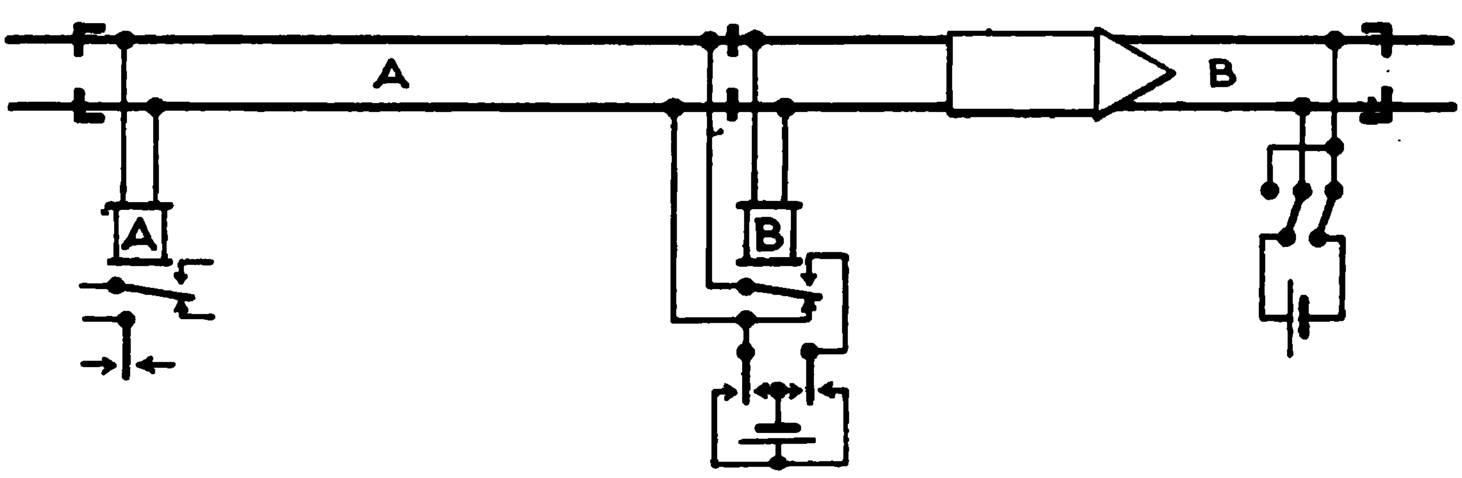

Fig. 112

*This is one of the uses of the *slow releasing relay.*

As will be noted, the neutral armature of relay B controls circuit A in the same manner as in Figs. 104-106.

The necessity of the polarized armature operating on a current below that required to pick up the neutral armature,* in relays whose polarized armatures continue to make contact, when the relay is de-energized, will be evident from a study of Figs. 110-112. For instance, if it should require *more* current to reverse the polarized armature of relay B, than is required to raise the neutral armature, assuming the current is just *above* the pick-up point of the neutral armature but *below* the operating point of the polarized armature, then if the pole changer should be reversed the neutral armature would be raised, and circuit A would be completed with the current flowing in the wrong direction, and consequently the polarized armature of relay A would be held in the wrong position. With the operating current of the polarized armature considerably below the pick-up current of the neutral armature, such a condition could not arise, because the polarized armature would be reversed *before* the neutral armature is raised.

181. Another method sometimes used to secure the change in polarity is shown in Fig. 113, applied to a relayed track

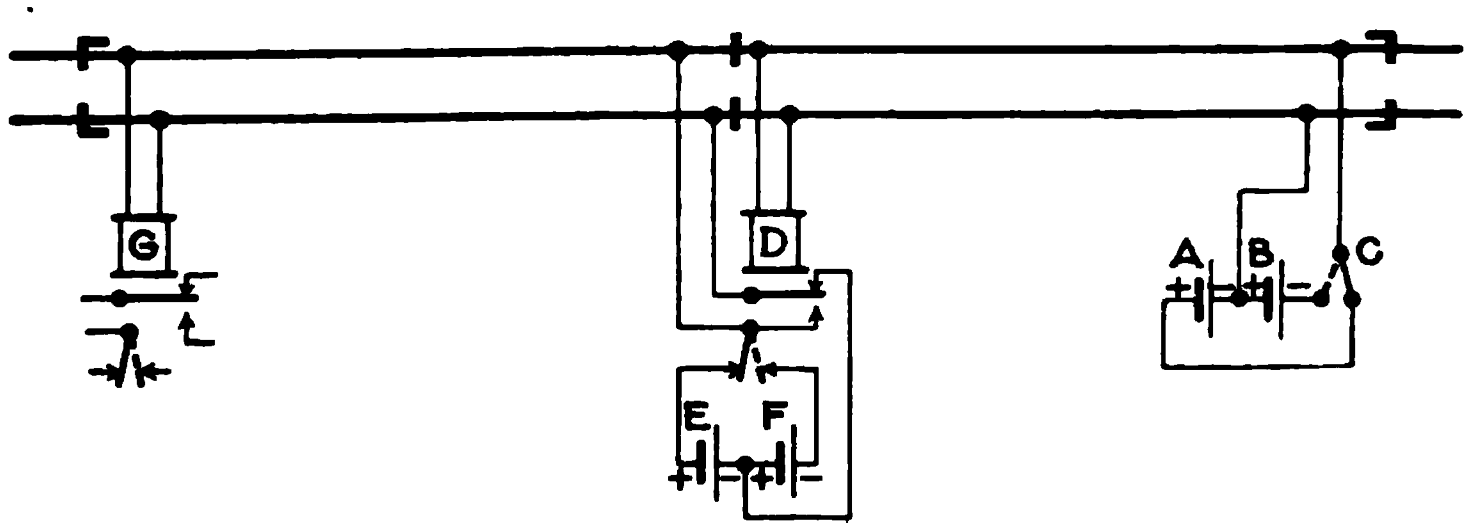

Fig. 113

circuit. It will be observed that *two* separate batteries are employed with each circuit, the terminals of *opposite polarity*, being connected to one wire and the remaining terminal of each, connected to a separate wire.

At the right of the illustration the wire from between the two batteries is permanently connected to the lower rail. The

*See Relays.

wire from the opposite terminal of either one or the other of the batteries, is connected to the upper rail, according to the position of the circuit controller C, which takes the place of the pole changer shown in Figs. 108-112.

With the circuit controller in the position shown, battery A is working and battery B is on open circuit, the *upper rail* being *positive* and the *lower rail, negative.* By reversing C, battery B is closed on to the track and battery A is placed on open circuit. As the negative terminal of battery B is now connected to the upper rail through the circuit controller, the *upper rail* will be *negative* and the *lower rail positive.* Thus the position of the polarized armature of relay D is governed by circuit controller C.

The polarized armature of relay D governs batteries E and F in the same manner as circuit controller C governs batteries A and B, thus controlling the polarized armature of relay G.

This arrangement although somewhat more expensive, is considered quite efficient, especially on relayed track circuits. The number of contacts required is less than in the single battery arrangement, which reduces the loss of energy due to resistance, that often develops in them. As either one battery or the other is always on open circuit, they each get some rest, which in the case of primary batteries, is very desirable. In some instances, the circuit controller occupies one position most of the time, being reversed occasionally for a few minutes only. In such cases, it is often convenient to use gravity cells in the battery which gets the most work, and potash or soda cells in the other battery.

MULTIPLE CLEARING RELAY CIRCUITS*

182. It is frequently convenient to have the presence of a train indicated at each end of a track circuit. In order to do this without the use of line wires, and also to assist in preventing interference from foreign currents, an additional relay is used as shown in Fig. 114.

In addition to the ordinary 4-ohm track relay A, a 16-ohm

*Other clearing relay circuits are described in Arts. 218-225.

relay B, is connected across the rails close to the battery. This

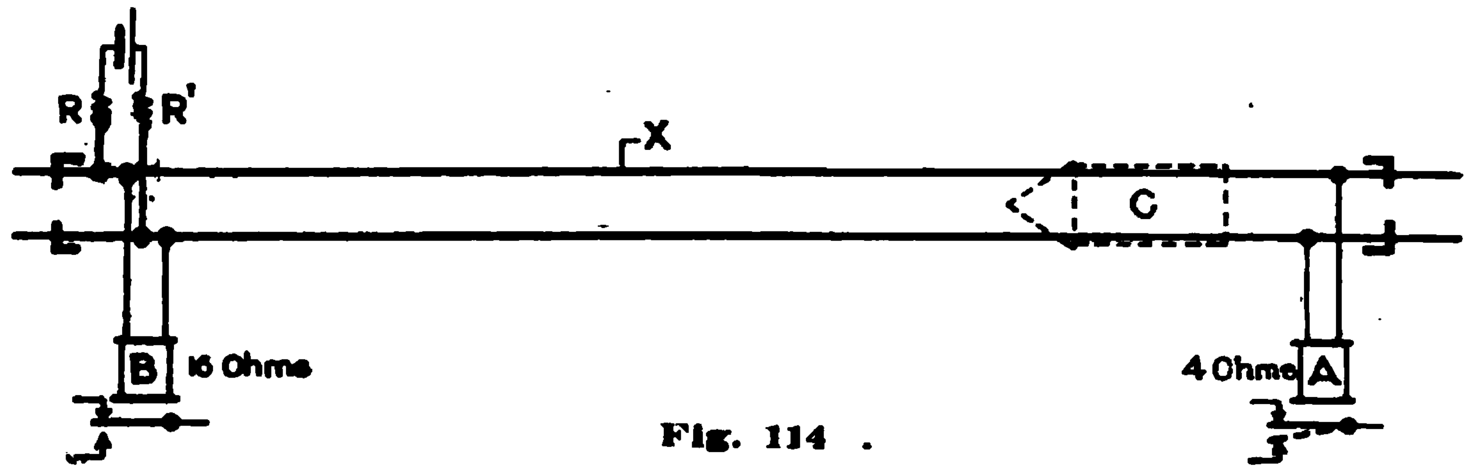

Fig. 114.

relay is adjusted to pick up at 36 mil-amperes, and release at 14 mil-amperes.*

183. In making calculations for either relay, the resistance of the *other* relay must be combined with the ballast resistance, and the result thus obtained used for value n in formula (3). For instance, assuming that a storage battery (2 volts), using an artificial resistance (R + R′) of 2 ohms, is employed and that the ballast resistance is 10 ohms; then, if it is desired to ascertain how much current will flow through relay A, when the track is *unoccupied*, the value of n must first be found, by combining the resistance of relay B with the ballast resistance, employing the rule for multiple resistances, thus;

$$\frac{16 \times 10}{16 + 10} = 6.154 \text{ ohms., } \textit{Ans.}$$

Using this value for n in formula (3),

$$i = \frac{2}{2 + 4 + \frac{2 \times 4}{6.154}} = .274 \text{ amp., } \textit{Ans.}$$

Therefore, the current flowing through relay A, when the track is *unoccupied* would be 274 mil-amperes.

184. To find the current through relay B, under the same conditions, the combined resistance of relay A and the ballast resistance is first computed, as follows;

$$\frac{4 \times 10}{4 + 10} = 2.857 \text{ ohms, } \textit{Ans.}$$

*R. S. A. Specifications.

Using this value for n in formula (3),

$$i = \frac{2}{2 + 16 + \frac{2 \times 16}{2.857}} = .0685 \text{ amp., } \textit{Ans.}$$

Therefore, the current through relay B, when the track is *unoccupied,* would be 68.5 mil-amperes.

185. **Problems.—In the following problems it is assumed that the track is *unoccupied.***

Assuming all values to be the same as those given in Art. 183, with the exception of the ballast resistance which is now assumed to be 25 ohms; (*a*) What will be the current through the 4-ohm relay? (*b*) What through the 16-ohm relay?

Answers.—(*a*) 293.3 mil-amp. (*b*) 73.3 mil-amp.

186. It will be noted that in these calculations, the current through the 4-ohm relay is exactly four times that through the 16-ohm relay; in other words, the current through these relays is inversely proportional to their resistances. In practice this will not always hold true, as with the formula used, no allowance is made for the resistance of the rails and wiring, which if considered, would slightly alter the results. The resistance of the rails will cause an *increase* of current in relay B, above that indicated by the calculations, and a corresponding *decrease* of that in relay A.

187. It will be noted that the voltage at which relay B releases (.224 volts), is considerably higher than that of relay A (.12 volt).*

The object of this adjustment is to allow for the effect of resistance in the rails and bonds upon the releasing of relay B. If a train should enter the circuit from the right and occupy the position shown at C, the wheels making good contact with the rails, the potential at the terminals of relay A would at once drop well below its releasing point. But with exceptionally high resistance in a bonded joint, for instance at point X, a much higher potential would be maintained at the terminals

*The drop-away points are expressed in volts to facilitate this explanation. The drop-away point in volts is, of course, obtained by multiplying the resistance of the relay by the drop-away current.

of relay B, which if adjusted to drop at the same voltage as relay A, might thus be kept from releasing until the train had passed point X. In fact, the same effect would be produced by any unusual resistance occurring between the shunt and the connections of relay B to the rail, either on account of poor bonding or a broken rail.

188. As an example of the foregoing, suppose the resistance at point X to be 4 ohms, that is, equal to that of relay A, then with a train at C, practically the same amount of current would flow through relay B, as it would receive when the track is unoccupied with no unusual resistance at X. In such an instance, therefore, relay B would not release until the train passes point X. Thus, in case of a broken rail, relay B will not only *fail* to detect it, when the track is unoccupied, but may also *fail* to indicate the presence of a train on a portion of the circuit. On account of the possibility of such failures, relay B is not depended upon to perform such important functions as those assigned to relay A.

189. If it is required to calculate the resistance which it is desirable to use for R and R′, Fig. 114, by formula (7); the value r should represent the resistance of relay B, and the value i its pick-up current, plus any *working margin* that it may be desired to allow. The resistance of relay A should be combined with the *minimum* ballast resistance, and the result thus obtained substituted for value n.

190. To illustrate this use of formula (7) it is assumed that the battery is arranged to give an effective E. M. F. of 8 volts, and that the minimum ballast resistance is estimated to be 1.8 ohms; also that a working margin of 10% is to be allowed above the pick-up current of relay B.

The combined resistance of relay A and the ballast resistance must first be found as follows;

$$\frac{4 \times 1.8}{4 + 1.8} = 1.241 \text{ ohms, } Ans.$$

Using this value for n in formula (7),

$$b = \frac{(8 \times 1.241) - (.0396 \times 1.241 \times 16)}{(.0396 \times 1.241) + (.0396 \times 16)} = 13.39 \text{ ohms, } Ans.$$

Therefore, under the given conditions, the total resistance of R and R′, should be 13.39 ohms, *less* the internal resistance of the battery.

191. PROBLEM.—On a certain track circuit, where it is desired to install a 16-ohm clearing relay in conjunction with a 4-ohm relay, the minimum ballast resistance is estimated to be 1.5 ohms. Allowing a working margin of 10%, what artificial resistance should be used with a 4-cell caustic soda battery, connected in series, each cell having an effective E. M. F. of .667 volts, and an internal resistance of .025 ohm?

ANSWER.—3.18 ohms.

192. The arrangement of relay resistances (4 and 16 ohms) shown in Fig. 114, has usually been found quite satisfactory, although in some cases other combinations may be found desirable.

193. Double-wound Clearing Relay Circuit: With a view to overcoming to some extent the weaker points of the arrange-

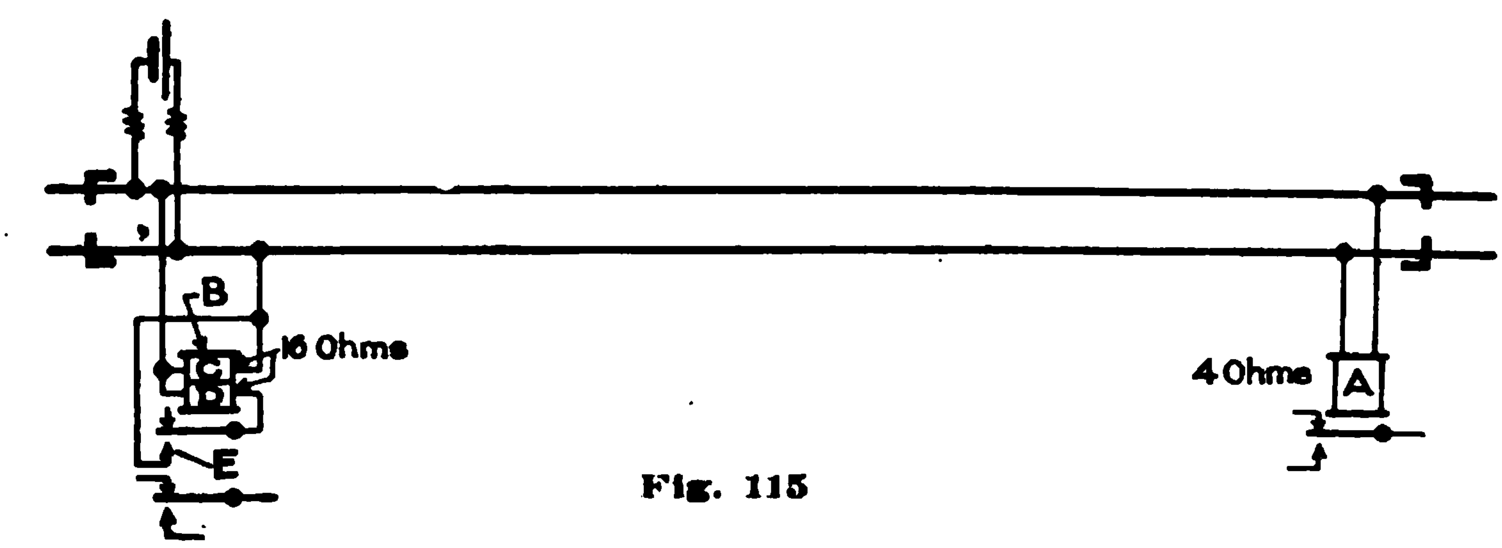

Fig. 115

ment shown in Fig. 114, the *double-wound* relay B, Fig. 115, has been devised.

This relay is provided with *two* 16-ohm windings, C and D, winding C being connected to the track in the same manner as relay B, Fig. 114, and winding D being connected in multiple with C, through a back contact E on the relay. Therefore when the armature is down, the resistance of the relay, is the joint resistance (8 ohms) of the two windings and owing to current passing through *both* windings, the maximum effect is produced upon the cores and armature. When enough current passes through the two windings to raise the armature, the back con-

tact E opens, thus *cutting out* winding D and leaving only winding C in circuit. As it requires much less energy to *retain* the armature elevated, than it does to *raise* it, the current passing through the single winding is sufficient to keep it in this position.

194. The 16-16 relay is usually adjusted to pick up with a current of 45 mil-amperes through the entire winding (8 ohms), or at a potential of .36 volts, and to release with 25 mil-amperes through the single winding (16 ohms), or at a potential of .4 volt. Thus a much *lower* pick-up voltage and also a much *higher* releasing voltage are secured, than with the 16-ohm clearing relay, (Fig. 114), both of which greatly favor the operation of the 16-16 relay. For instance, on account of its *higher* drop-away point, the 16-16 relay is more likely to operate in case of a broken rail or defective bonding, although of course it will not detect a broken rail, when the track is unoccupied.

195. When calculating the battery arrangement required for a track circuit, similar to that illustrated in Fig. 115, it is first necessary to ascertain that any proposed battery will operate the 16-16 relay, with a proper working margin. This is done as explained in Art. 184, in which the ballast resistance is combined with that of the 4-ohm relay, for value n, to be used in formula (3), for finding the current through the clearing relay.

It should be remembered that when de-energized, the resistance of the 16-16 relay is 8 ohms, which in formula (3) should be used for value r, when calculating whether the proposed battery arrangement will pick up the 16-16 relay, with the proper working margin.

The next step is to make certain that after the armature is raised, enough current will continue to flow through this relay to insure a proper working margin *above* the drop-away point. This is found by using formula (3) as just explained, substituting 16 ohms in place of 8 ohms, for the value of r.

196. The foregoing method is used to advantage when calculating gravity battery arrangements, but when employing storage or other batteries of low internal resistance, the proper value for the artificial resistance may be obtained by using for-

mula (7) as described in Art. 190. In this case, E is of course, an assumed value; n is the combined resistance of the ballast and the 4-ohm relay; i is the pick-up current of the 16-16 relay plus a proper working margin; and r the joint resistance (8 ohms) of the two windings of this relay. When the artificial resistance has thus been computed, a proper working margin, *above* the drop-away point, should be assured, as explained in the last paragraph of Art. 195.

197. When a battery arrangement, which will operate the 16-16 relay properly, has been determined upon, the current through the 4-ohm relay, may be calculated as explained in Art. 183.

198. The resistance of 16 ohms in each winding of relay B, with 4 ohms in relay A, usually makes a satisfactory arrangement, but other combinations are also used, one being a 24-24 relay at the battery and a 4-ohm relay at the other end of the circuit.

OVERLAP TRACK CIRCUIT

199. When it is desired to extend the indication of one relay over a length of track controlling another, the arrangement shown in Fig. 116 is sometimes used. It will be observed that

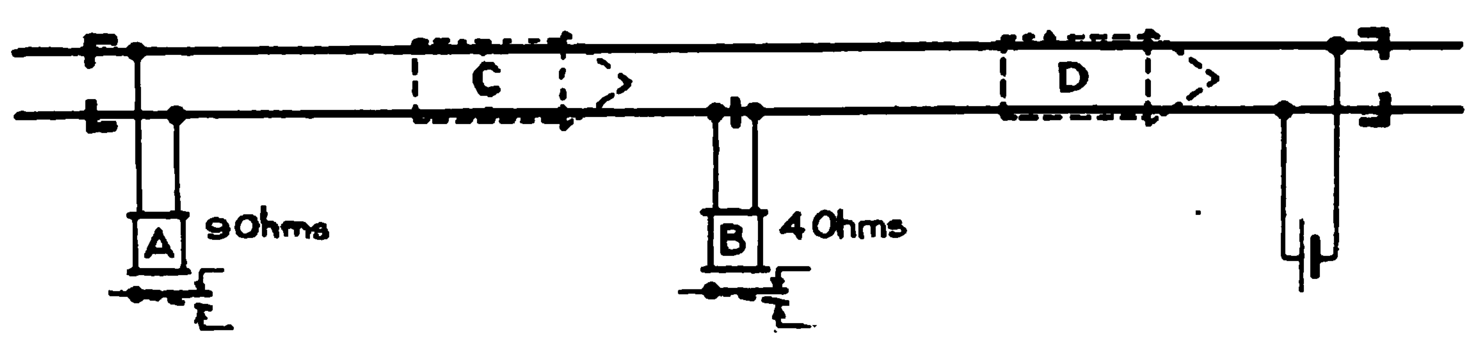

Fig. 116

one battery supplies current for both relays, an insulated joint being placed in one rail, and the circuit *looped* around it, through relay B as indicated.

When a train occupies a position between the two relays, as shown dotted at C, relay A, *only* is de-energized, relay B still receiving current which passes through the wheels of train C. When the train is between relay B and the battery, as shown at

D, *both* relays are de-energized. Thus the indication of relay A *overlaps* that of relay B.

Relay B, being nearer the battery, is favored in picking up, as any current which leaks through the ties and ballast between the two relays, must of course, pass through it. It is therefore usually wound to a lower resistance than relay A, giving the latter the benefit of their difference. The combination shown (4 and 9 ohms) may be made to operate satisfactorily.

NORMALLY OPEN TRACK CIRCUITS

200. A track circuit operating on a principle opposite to those heretofore described, is illustrated in Figs. 117-118. It is known as a **normally open track circuit.**

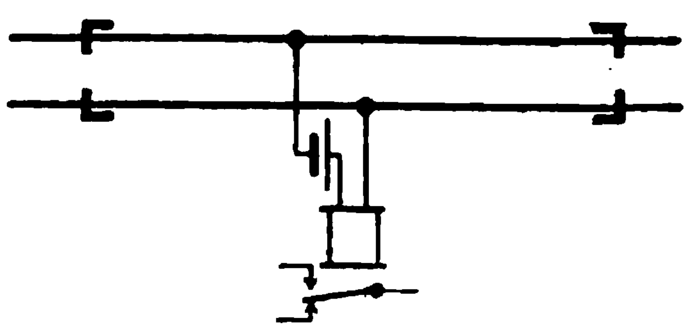

Fig. 117

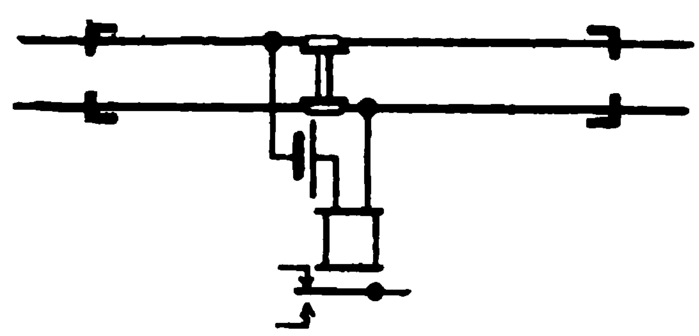

Fig. 118

NOTE.—The term **normally open** is applied to this type of track circuit, first, because the battery is, in its *normal* condition (when the track is not occupied by a train), on *open* circuit, (except leakage through ties and ballast); and second, because under like conditions, the relay also is *open*.

If a circuit controller should be inserted as a part of a *normally closed* track circuit, arranged so as to keep the circuit open, except when it is occasionally necessary for the relay to be closed to perform some operation, it would be proper to term such an arrangement, a "normally open" track circuit. However, as this arrangement is uncommon, the term has not been generally so applied.

201. With the arrangement shown in Figs. 117-118, the relay is directly *in series* with the battery and the entire current passes through it. When the track is unoccupied, Fig. 117, the small amount of current passing from rail to rail, through the ties and ballast, is *below* the drop-away point of the relay, and consequently the armature remains down.

202. With the track occupied, Fig. 118, the conductivity of

the path through the wheels and axles is added to that of the ties and ballast, forming a good path for the flow of current, thereby causing the relay to pick up.

Thus the relay indicates the presence of a train within the limits of the circuit, but in a manner opposite to that of the normally closed track-circuit; that is, the armature is *picked up,* instead of being *released,* by the presence of a train.

203. Calculations: It will be observed that the formulas given for calculations in connection with the normally closed track circuit, do not apply to the normally open circuit.

As the entire current output from the battery, passes through the relay, it is evident that the values i and I (Art. 112) are equal, and therefore but one letter is required to express them. Using the letters, except I, given in Art. 112 to represent the values, the following formulas may be used.*

To find the current passing through the relay when the track is *unoccupied;*

$$i = \frac{E}{b + r + n}. \qquad (8)$$

To find the current passing through the relay when the track is *occupied* by a train;

$$i = \frac{E}{b + r + \frac{ns}{n + s}}. \qquad (9)$$

204. To illustrate the use of these formulas the following values are assumed;

$E = .7$ volt.
$b = .15$ ohm.
$n = 50$ ohms.
$r = 4$ ohms.
$s = .05$ ohm.

Using these values in formula (8),

$$i = \frac{.7}{.15 + 4 + 50} = .0129 \text{ amp., } \textit{Ans.}$$

*The resistance of the wiring is not taken into account in these formulas, although if large enough to be considered (as may sometimes happen when either the battery or the relay are some distance from the track) it should be added to the internal resistance of the battery.

Therefore the current passing through the relay when the track is *unoccupied,* is 12.9 mil-amperes. This current being *below* the drop-away point of the relay, its armature will, under the assumed condition, remain down.

Using the same values in formula (9),

$$i = \frac{.7}{.15 + 4 + \frac{50 \times .05}{50 + .05}} = .1667 \text{ amp., } \textit{Ans.}$$

Therefore the current passing through the relay when the track is *occupied,* is 166.7 mil-amperes. This current being *above* the pick-up point of the relay, its armature will be raised.

205. Problems.—With the values given in Art. 204, with the exception that a $3\frac{1}{2}$-ohm relay is used; (*a*) What will be the current through the relay when the track is unoccupied? (*b*) What when occupied?

Answers.—(*a*) 13 mil-amp. (*b*) 189.2 mil-amp.

206. As it is necessary, when the track is unoccupied, that i be *less* than the drop-away current of the relay, it is evident that the *lower* the value of n, the *lower* must be the value of E, other values remaining the same. Therefore, if it has been decided to use a certain relay, and the minimum value of n is estimated, and also that of b for any proposed battery arrangement, the maximum value for E may be found by using formula (8) arranged as follows;

$$E = i(b + r + n). \qquad (10)$$

In this case i represents the *drop-away* current of the relay, *less* any percentage that it may be desired to allow as a working margin.

207. As may be inferred from Art. 206, the *lower* the value of E the *lower* may be the value of n; however, the value of E must always be high enough to pick up the relay, when the track is occupied. Therefore, if it has been decided to use a certain relay, and the maximum values of n and s are estimated, also of b for any proposed battery arrangement, the minimum

value for E may be found by using formula (9) arranged as follows;

$$E = i\left(b + r + \frac{ns}{n+s}\right).$$

As the maximum value of n is, in practice, often difficult to determine, and as the joint resistance of n and s cannot, in any case, exceed that of s, it is apparent that, if in this formula, s be substituted for $\frac{ns}{n+s}$, the resulting formula will produce a *slightly higher* voltage, which only tends to further insure the proper operation of the relay. This substitution is made as it simplifies the formula as follows;

$$E = i(b + r + s). \qquad (11)$$

In this case, of course, i represents the pick up current of the relay, *plus* a proper working margin.

208. To illustrate the use of formulas (10) and (11), 25 ohms is taken as the minimum value of n, the other values used (excepting E and s) being the same as given in Art. 204. A margin of 10% below the drop-away current of the relay is allowed, formula (10) reading as follows;

$$E = .027\ (.15 + 4 + 25) = .787 \text{ volt, } \textit{Ans.}$$

Assuming 2 ohms to be the maximum value for s, and that a margin of 10% is allowed above the pick-up point of the relay, formula (11) reads as follows;

$$E = .0715\ (.15 + 4 + 2) = .44 \text{ volt, } \textit{Ans.}$$

Therefore, under the assumed conditions, the maximum effective E. M. F. which may be used is .787 volt, and the minimum, .44 volt.

209. PROBLEMS.—On a certain normally open track circuit, the minimum ballast resistance of which is estimated to be 20 ohms, it is proposed to use a 3½-ohm relay.* The maximum value of b is assumed to be .2 ohms, and that of s 1.5 ohms. It is desired to allow a working margin of 10% for both the pick-up and drop-away current.

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*For pick-up and drop-away current see Fig. 89.

What will be the (*a*) maximum and (*b*) minimum effective E. M. F. allowable?

ANSWERS.—(*a*) .68 volt. (*b*) .38 volt.

210. Reducing the ballast resistance of a normally open track circuit tends to cause the relay to *remain energized,* after a train leaves the circuit. Therefore, if it is desired to find the maximum length of track circuit, that can be operated with a certain relay and battery arrangement, the minimum value of n may be found for this purpose by using formula (8), arranged as follows;

$$n = \frac{E}{i} - (b + r). \qquad (12)$$

In this case also, i represents the drop-away current of the relay *less* the percentage allowed as a working margin.

211. To illustrate the use of this formula, the values given in Art. 204 (excepting that of n) are taken, and a working margin of 10% is allowed, *below* the drop-away point of the relay. The formula then reads;

$$n = \frac{.7}{.027} - (.15 + 4) = 21.78 \text{ ohms, } \textit{Ans.}$$

Therefore, to insure the proper *releasing* of the relay, the *length* of any circuit to which the above conditions will apply, must be such that the ballast resistance *will not* be less than 21.78 ohms. For instance, the ballast resistance, under uniform conditions, is inversely proportional to the length of the circuit (Art. 111). Consequently, if a circuit similar to the above is installed on a track whose minimum ballast resistance is estimated at 3 ohm per 1,000 ft., then of course, 3 $\times$ 1000 ft. or 3,000 ft. of this track would have a ballast resistance of 1 ohm. As it is necessary that the ballast resistance of the circuit be not less than 21.78 ohms, then 3000 ft. $\div$ 21.78 will give the length of track having this ballast resistance, thus,

$$\frac{3 \times 1000}{21.78} = 137.7 \text{ ft., } \textit{Ans.}$$

Therefore, under the assumed conditions 137.7 ft. is the *maximum* length of circuit which can be operated.

212. From the foregoing the following conclusions may be drawn: First, *reducing* the resistance of the relay tends to *favor* the operation of the circuit; second, *reducing* the effective E. M. F. of the battery also tends to produce the same result, but in a less degree; third, *increasing* the internal resistance of the battery (or artificial resistance), while it may afford relief in case of low ballast resistance, it *decreases* the efficiency of the circuit to operate in case of poor wheel contact; fourth, if for any reason it is not desirable to reduce the effective E. M. F. of the battery, the same result in operation may be obtained by *adjusting* the relay to work on a *higher* drop-away and pick-up current.

With the normally open, as with the normally closed track circuit, the closer the pick-up and drop-away points of the relay are to each other, the more favorable will be the results obtained.

213. It is not desirable to employ gravity batteries on normally open track circuits for the following reasons; first, cells of this type need more work to keep them in good condition*, than would be usually required of them on such circuits; and second, their comparatively high internal resistance tends to interfere, as explained in Art. 212, with the operation of the circuit.

Caustic soda or potash cells are especially adapted to such circuits, and where traffic is not too heavy, salammoniac or dry cells will work satisfactorily.

214. By omitting the two insulated joints in either the upper or the lower rail (Figs. 117-118), a *single rail* normally open track circuit will be produced. Such an arrangement will operate satisfactorily, especially on a short circuit, although the lower ballast resistance resulting (Art. 125), would tend to prevent the relay from releasing properly.

215. Broken Rails: The effects produced by a broken rail in a normally open track circuit are as follows: With

*See **Magnetism and Electricity**—*Batteries*.

the rail, broken at point X, Fig. 119, there may not be enough

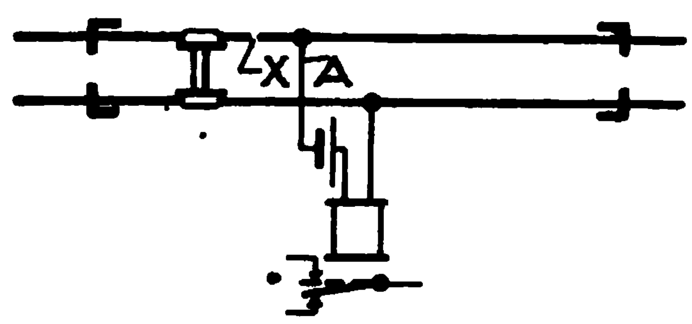

Fig. 119

current passing from wire A to the wheels of the train, entering the circuit from the left, to cause the relay to pick up, in which case the armature will remain down until the train passes over the break in the rail. Enough current might pass around the break to hold up the armature if once lifted, in which case the relay would operate as usual for a train moving in the opposite direction. In other instances, enough current might pass around the break to operate the relay as usual thus preventing it from giving any indication of a broken rail. The effect would, of course, be practically the same, if the rail were broken at any other point in the circuit.

Thus in case of a broken rail, the relay will not only *fail* to detect the fact when the track is unoccupied, but may also *fail* to indicate the presence of a train on a portion of the circuit.

216. Defective Conditions: If the circuit should be broken at any point in the wiring, by a break in the wire, a corroded joint or a loose binding post, the relay will *fail* to indicate the presence of a train, and the circuit *will not indicate its defective condition,* except when a train is present on the track.

On account of the possibility of such failures, the normally open track circuit is ordinarily not as desirable as the normally closed circuit for operating signal apparatus.

217. Normally open track circuits are seldom operated over more than a few hundred feet of track, and, although by the use of properly arranged relays, batteries, etc., this length might be considerably increased, its limited application has not required that it be carried to the degree of development found in the normally closed circuit.

SERIES CLEARING RELAY CIRCUITS

218. An arrangement which is, in effect, a combination of

the normally closed and normally open track circuits, is shown in Fig. 120. Relay A operates as in the ordinary normally

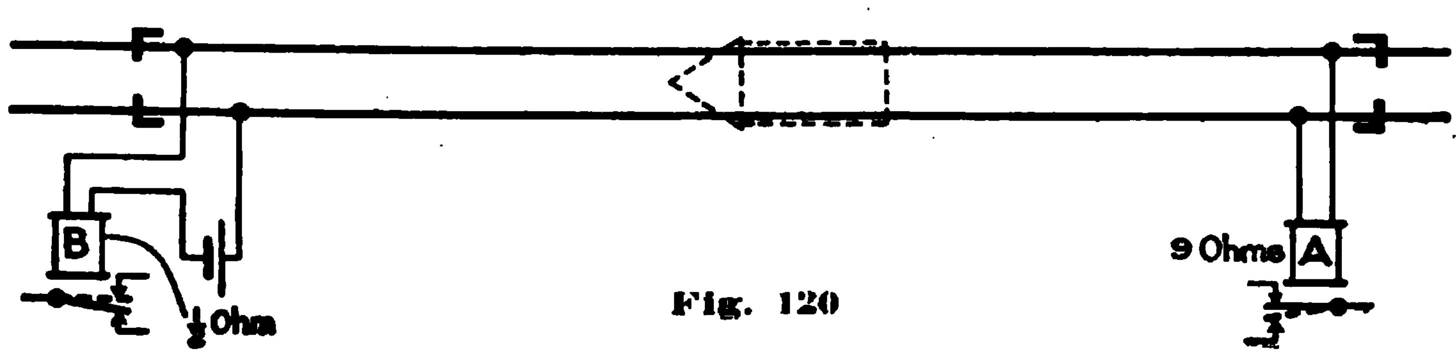

Fig. 120

closed circuit. Relay B, which is inserted in one of the battery leads, operates as in the normally open circuit, and incidentally takes the place of any artificial resistance, that might otherwise be used. The effect of the presence of a train shown dotted, is indicated by the dotted position of the armatures.

219. In making calculations for relay A, the resistance of relay B is considered as a part of b in formulas (1) to (6) inclusive, and likewise in making calculations for relay B, the resistance of relay A is combined with that of the ballast, and the result thus obtained is substituted for n in formulas (8) to (10) inclusive.

220. As the resistance of relay A, in any given arrangement, is a fixed quantity, it should be combined with the maximum value of s and the result thus obtained substituted for value s in formula (11), when making calculations for relay B.

221. The resistances given in the illustration (½ and 9 ohms) make an available combination, although other arrangements may be used. By making calculations with formulas (8) to (12) inclusive, it will be found that with a resistance of 12 ohms or less in relay A, the resistance of relay B, with the ordinary adjustment,* cannot be made much greater than one ohm. The principal reason for this of course is the fact that the effective E. M. F. of the battery must be kept high enough to operate relay A. However, by altering the adjustment of relay B, as mentioned in Art. 212, its resistance may be increased where necessary.

*.015 watt pick-up.

222. The operation of relay B in case of a broken rail will, of course, be the same as described in connection with the ordinary normally open track circuit.

223. The gravity battery, on account of its high internal resistance (Art. 213), is not well adapted to this type of circuit.

DIFFERENTIAL CLEARING RELAY CIRCUIT

224. A circuit which combines the principles illustrated in Figs. 114 and 120, is shown in Fig. 121. The differential relay

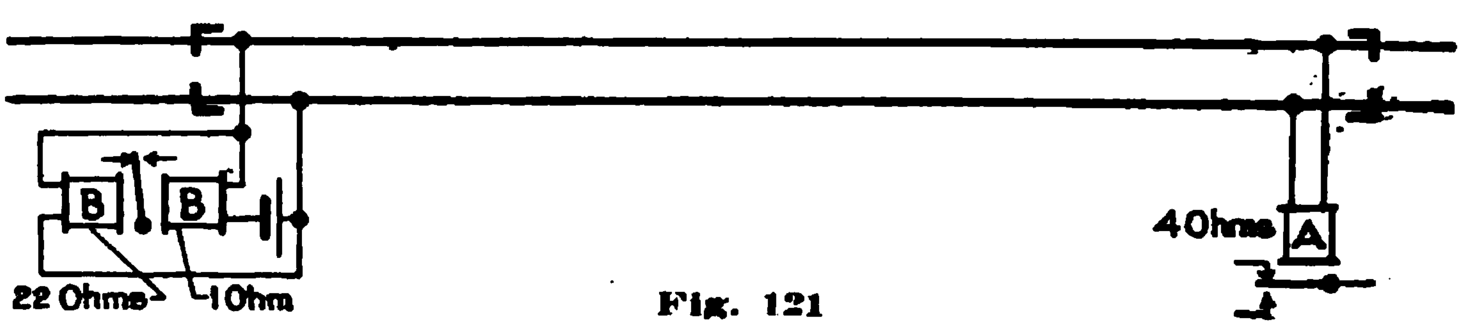

Fig. 121

B, which is constructed with *two* pairs of coils, is mounted horizontally so that the movement of their armatures will not be biased by gravity. Each magnet has its own armature, but the two armatures are *rigidly connected,* so that they are attracted by whichever magnet is the stronger.

225. The 22-ohm coil, Fig. 121, represents relay B in Fig. 114, and the 1-ohm coil, relay B in Fig. 120. By comparing those two relays it will be observed that their operation is directly opposite; that is, with one the armature is attracted when the track is unoccupied and released by the presence of a train, while with the other the armature occupies the opposite position under like conditions. Therefore, when connected as shown in Fig. 121, the operation of the two magnets is reciprocal, each attracting as the other releases.

There are no fixed pick-up and releasing points for the magnets, as, of course, the reversal of their armatures is dependent upon the ratio which the current in one coil bears to that in the other, and thus ordinary variations in battery power have practically no effect upon the operation of the relay.

The differential relay is usually adjusted to operate through a rail resistance as high as one ohm,* and, with a 4-ohm relay at the other end of the circuit, it will operate properly on a ballast resistance as low as 4 ohms. The ratio of the resistances, 1 and 22 ohms in relay B, and 4 ohms in relay A is usually satisfactory, although other combinations may be used.

ARRANGEMENTS AT SWITCHES**

226. When a switch is located in a track circuit, it is evident that without some means to prevent the current from passing from rail to rail, as explained in connection with Fig. 17, the switch rods and cross-rail would tend to act in the same manner as a pair of wheels on the track, thus keeping the relay de-energized, and therefore falsely indicating the presence of a train. To prevent the switch from thus interfering with the operation of the circuit, the methods explained in Arts. 23-43, are employed.

227. Another method sometimes used is shown in Fig. 122. Two insulated joints C and D are placed in rail B, and a wire

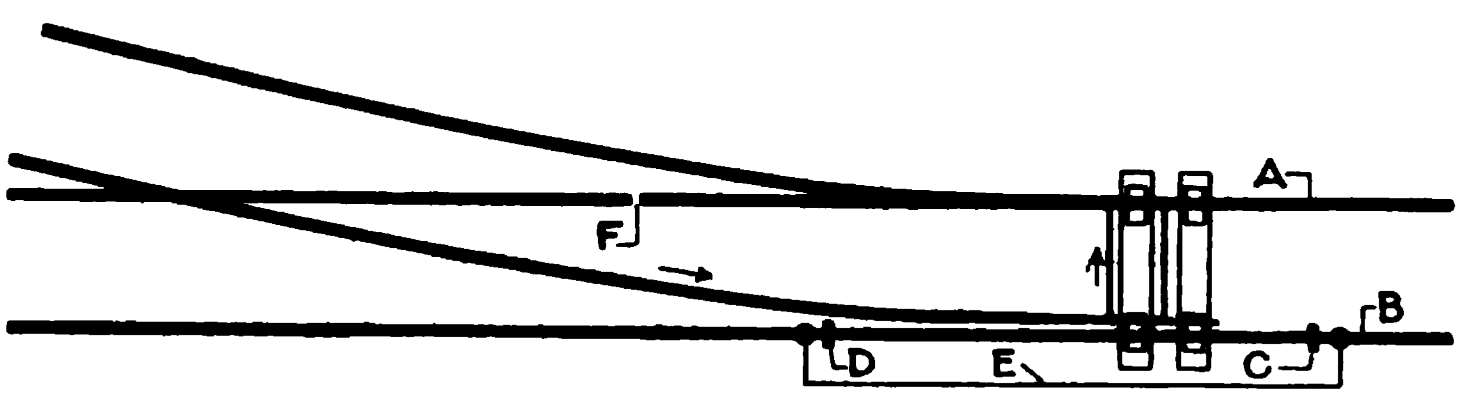

Fig. 122

E, known as a *jumper*, is connected as shown. The current in rail B will then pass through wire E, around the length of rail between C and D, which is the only part of rail B that can be reached by current from rail A.

This portion of rail B between the insulated joints is said to be *cut out* or *dead* and it is apparent that the relay will not

*As might occur in case of defective bonding.

**These arrangements are explained in connection with normally closed track circuits, although they may be adapted for use with normally open track circuits.

be affected by a pair of wheels occupying it* or by a break in the rail between the two insulated joints. This fact constitutes one of the principal objections to this arrangement, as it is very desirable to have as little dead track as possible in a circuit. Another objection to this arrangement, which also applies to the use of wedge blocks, Fig. 32, is the path formed by the cross rail and switch rods (shown by arrows) for current to pass around a break in the rail at point F, which would probably prevent the circuit from detecting the broken rail.

228. It is frequently desirable, when a switch is located in a track circuit, to prevent the current from passing into the siding rails, because if allowed to reach any great length of rail, as might occur in a yard or long turnout, the ballast resistance of the circuit would be considerably reduced. Also, as shown in

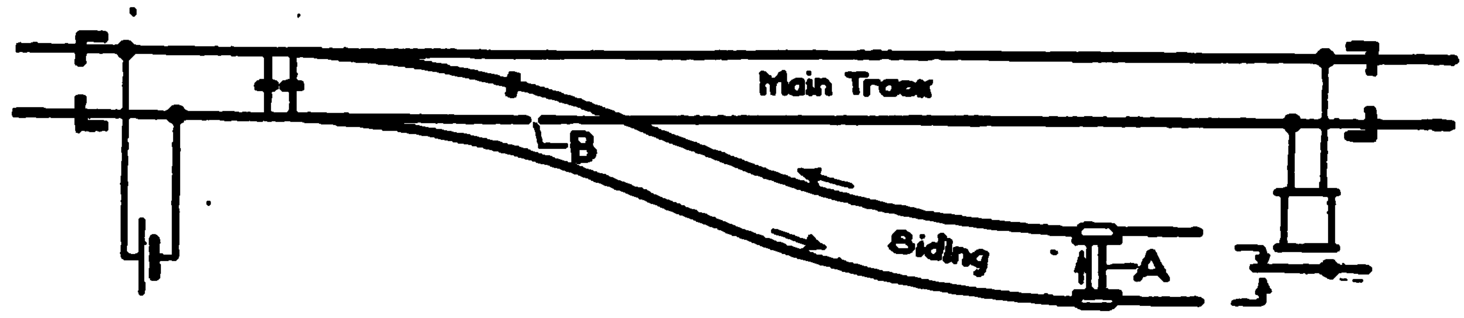

Fig. 123

Fig. 123, a car on the siding at A might prevent the circuit from detecting a broken rail, in the main track at B, by forming a path (shown by arrows) around it.

229. If two switches in the circuit were both connected to the same siding, as shown in Fig. 124, two paths (shown by

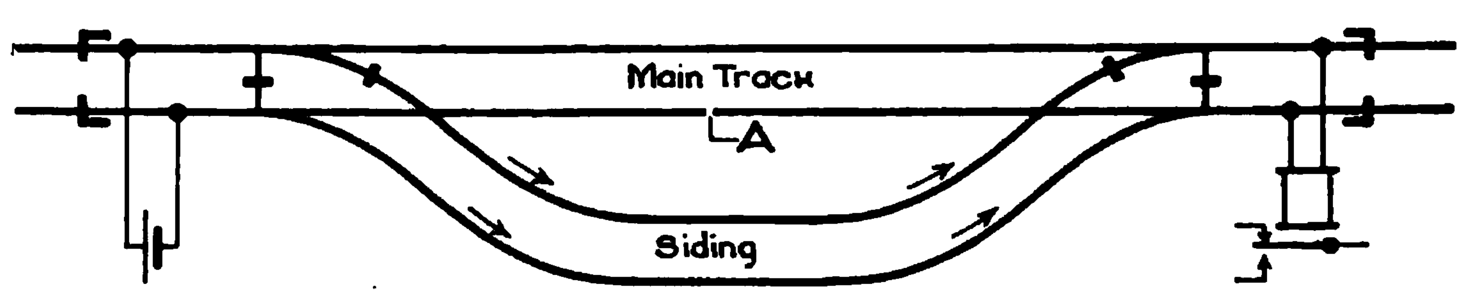

Fig. 124

arrows) would be formed for current to pass around a break in the rail at point A. However, in certain classes of work,

*This dead section is usually so short that it cannot hold an entire car and therefore the wheels that extend beyond the insulated joint will keep the relay de-energized.

which do not demand broken rail protection, the arrangement shown in Figs. 123-124, may be used for circuits of moderate length.

230. In order to avoid failures from low ballast resistance, and also to provide where necessary, as much broken rail protection as possible, it is customary to place insulated joints in the siding rails as shown at A and B in Fig. 125.

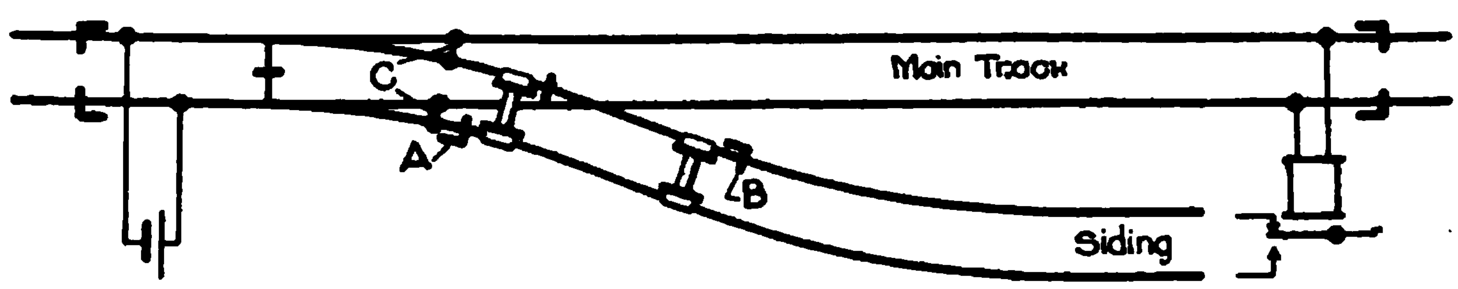

Fig. 125

NOTE.—The jumpers C, Fig. 125, represent bonding required to insure good conductivity through the switch.

231. Fouling Protection: If a train should move from the siding shown in Fig. 125, toward the switch, the relay would not be shunted until the first pair of wheels had passed over insulated joint A, because when the wheels are in either of the positions shown, one wheel is on a *live** rail and the other on a *dead* rail. If the insulated joint should be placed at point C instead of point A, Fig. 126, as might occur in some

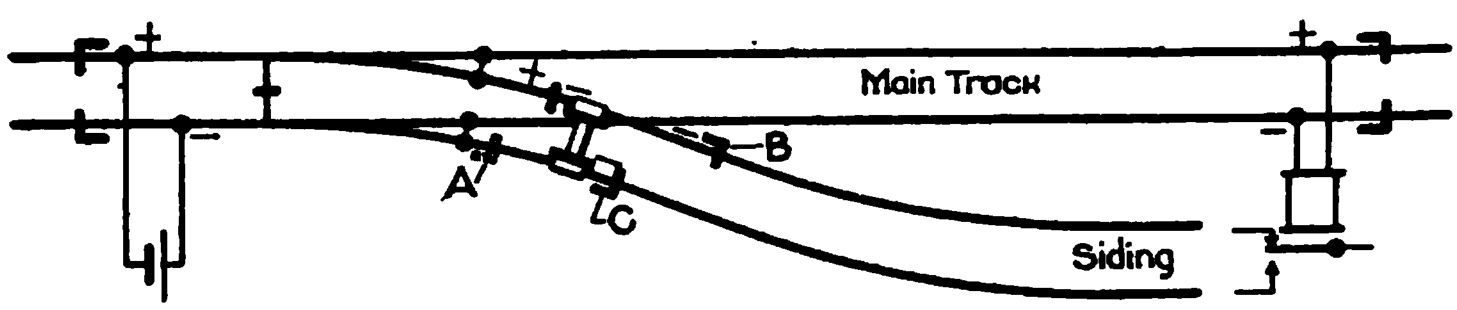

Fig. 126

cases, the wheels when in the position shown, would *both* be on *live* rails, but of the *same polarity,* and therefore they would not shunt the relay. Thus a car could be moved from the siding far enough to block the main track (and so render it unsafe for another train to pass) without causing the relay to indicate its presence.

*Energized.

232. As the normally closed track circuit is largely used to indicate whether or not the track is safe for the passage of a train, it is necessary in such cases, that the circuit be so arranged that it will indicate the presence of the wheels on the siding, not only as shown in Figs. 125-126, but at *any point* where a car on the siding rails would *foul* with one on the main track.

233. This result is obtained by using the arrangement shown in Fig. 127. The insulated joint B is moved back from the

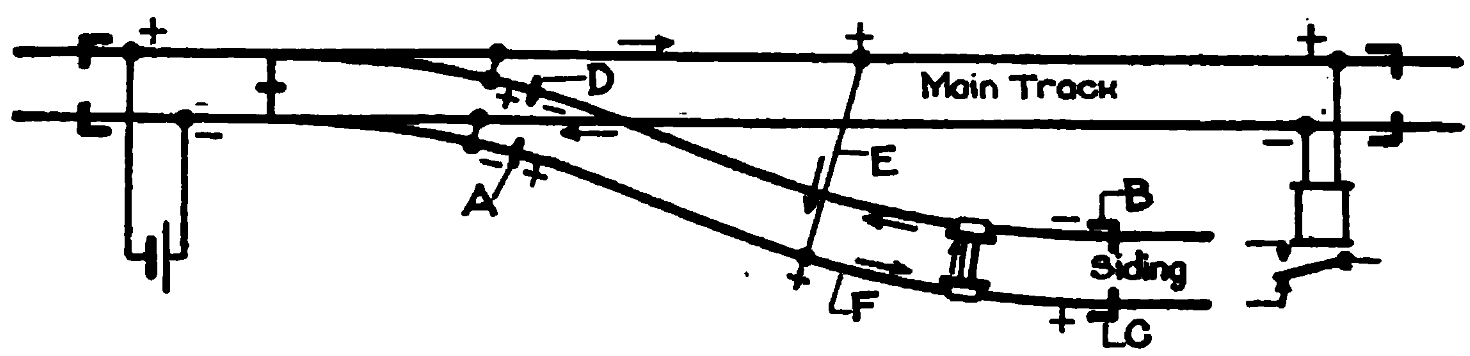

Fig. 127

position near the frog shown in Figs. 125-126, to the **fouling point**, that is, the point in the siding at which a car moving from it would begin to foul with a car on the main track. Another insulated joint C, is placed opposite B, a jumper E connecting that position of the siding rail between joints A and C with the further rail of the main track. The jumper is of such a size that its resistance need not be considered. Thus any pair of wheels on the siding between the fouling point and the switch, comes into contact with both the positive and negative rails of the circuit, and therefore (as shown by arrows) shunts the current out of the relay.

234. The insulated joints A and D should, of course, be as nearly opposite as possible in order to reduce to its minimum the dead section that will occur between them if *staggered*. It is also desirable that joints B and C be as nearly opposite as possible, because, if staggered, a pair of wheels might be left standing between them, which would tend to lessen the ballast resistance by forming a path for current to pass into the siding, (Art. 228).

235. The jumper E should be connected to the siding rail as nearly as possible half way between joint A and the fouling

point. This is desirable because this rail is not connected *in series* with the battery and relay as are the main track rails, but *in multiple.* Therefore if the rail should break or the bonding become defective at point F, the relay would not only fail to detect this condition when the track is unoccupied, but also might fail to indicate the presence of a pair of wheels on any part of the track between point F and joint C. As a similar condition would be produced by a broken rail or defective bonding at any point between joints A and C, it is apparent that, with the jumper connected midway between them, more than half of this rail would, in any case, still be effective in shunting the relay.

236. It will be observed that if jumper E should become disconnected or broken, the relay would operate properly for a train on the main track but not for one on the siding. There would be no warning that the jumper was broken and thus a dangerous condition might remain undiscovered for some time. In order to guard against such a failure, two jumpers B and D, Fig. 128, are sometimes used, it being assumed that they will

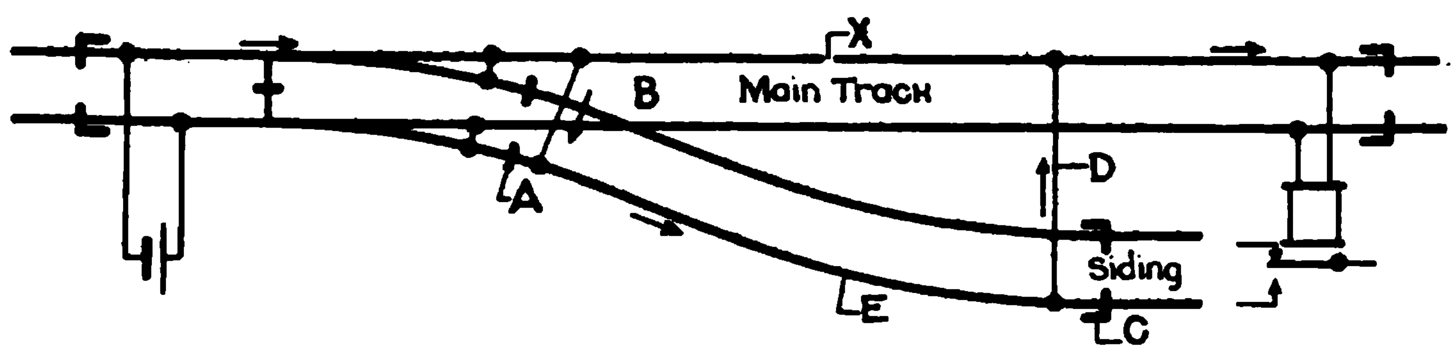

Fig. 128

not both become disconnected at the same time. Another advantage of this arrangement is that in case of a broken rail or poor bonding, for instance at point E, the entire siding rail, between joints A and C, would still be connected and would shunt the relay through either one or the other of the jumpers.

237. The double jumper arrangement, shown in Fig. 128, has this objection; if a break should occur in the main rail between the points where the two jumpers are attached, as at point X, the current would still have a path (shown by arrows) and the relay would fail to indicate the presence of the broken rail.

This objection is overcome by the arrangement shown in Fig. 129, in which an insulated joint is placed in the main rail

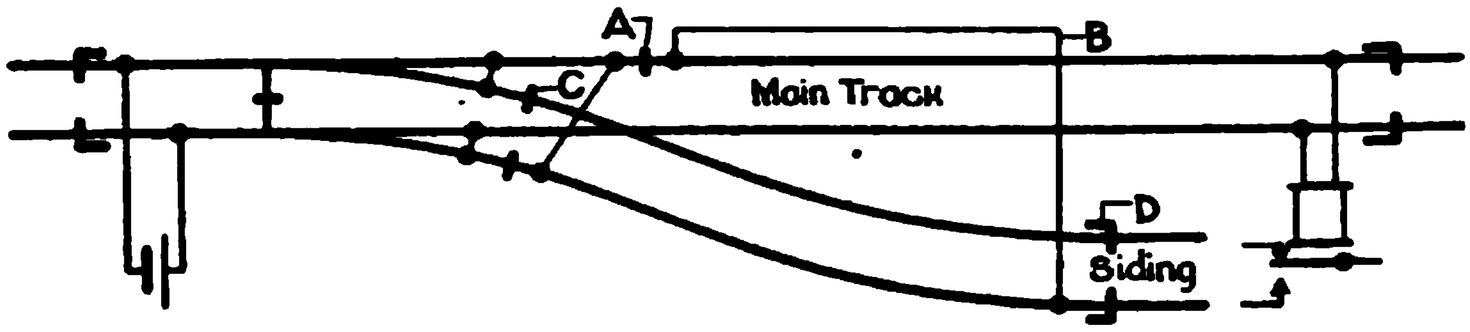

Fig. 129

at A and the two jumpers connected close to it. Thus the section of the siding rail, is placed *in series* with the main rail, instead of *in multiple* or *shunt,* as in Figs. 127-128, and a broken rail or poor bonding in this portion of the siding rail will be as effective in dropping the relay as if in the main rail. Of course, there is a possibility of a breakdown of insulation in joint A, in which case there would be nothing to indicate the fact, and the siding rail would then be in multiple, as in Fig. 128. While in this event one of the jumpers, B, would be longer than is desirable, yet owing to the jumpers being connected to the main rail only a few feet apart, there would not be as much possibility of a failure to indicate a break in the main rail, as in Fig. 128.

In this connection, it should be observed that the rail between joints C and D is still in multiple. However, it is not usually considered practicable to develop the series arrangement further than that shown in Fig. 129.

ARRANGEMENTS AT GRADE CROSSINGS

238. When a grade crossing occurs in a track circuit, it may be protected as shown in Fig. 130. This arrangement is applic-

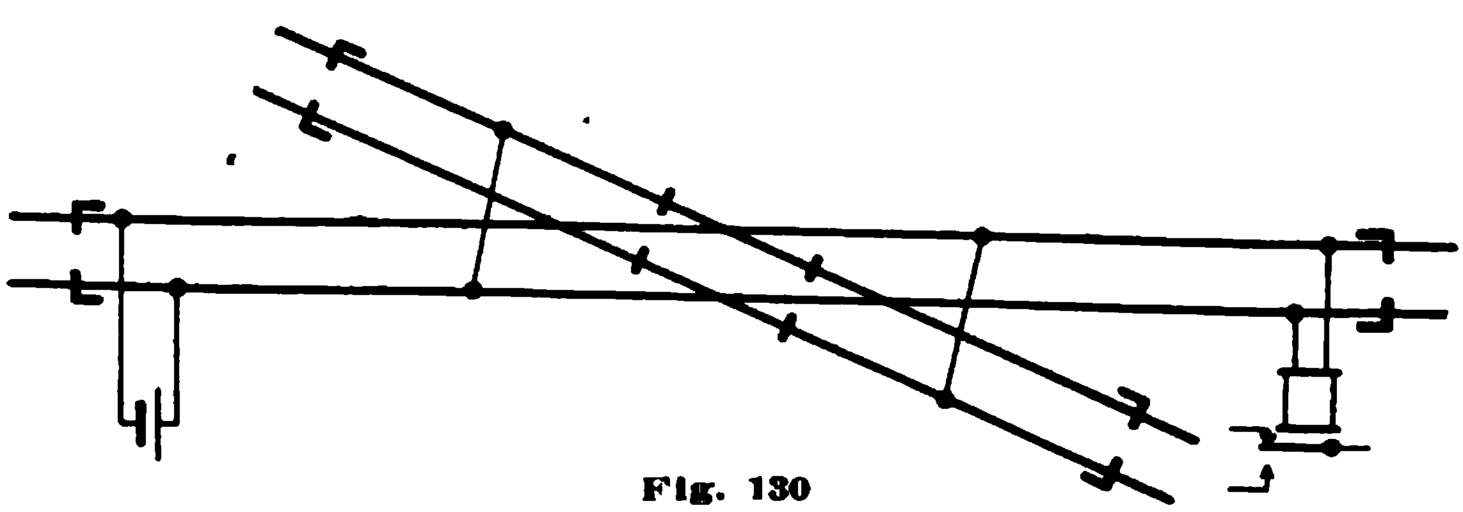

Fig. 130

able either to rigid or movable point frogs, although in the latter case, the rods connecting the frog points must be insulated.

239. Other methods used to carry circuits through crossings are shown in Figs. 131-134. These arrangements are not de-

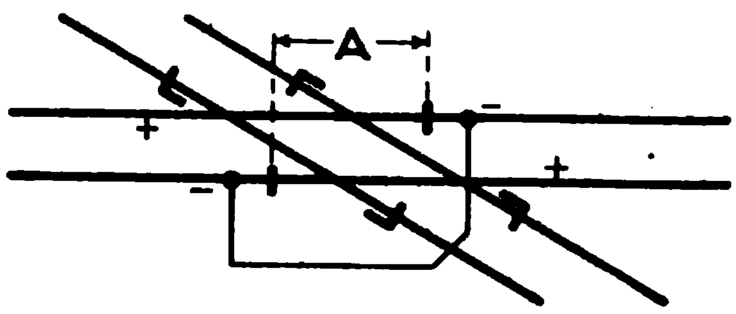

Fig. 131

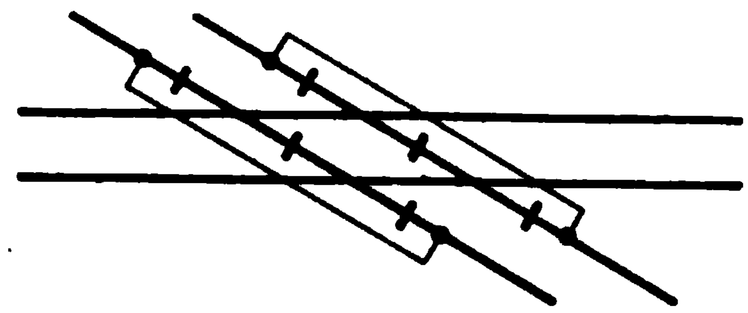

Fig. 132

signed to provide fouling protection, such protection being secured by other means. The arrangement shown in Fig. 131, is used where it is not desired to install insulated rail joints in

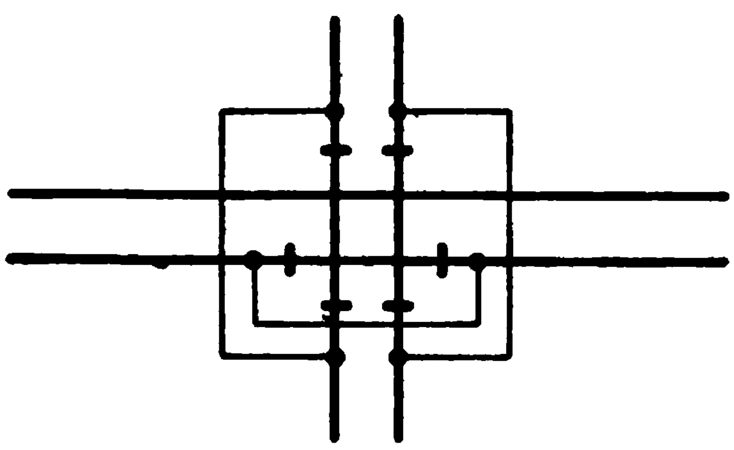

Fig. 133

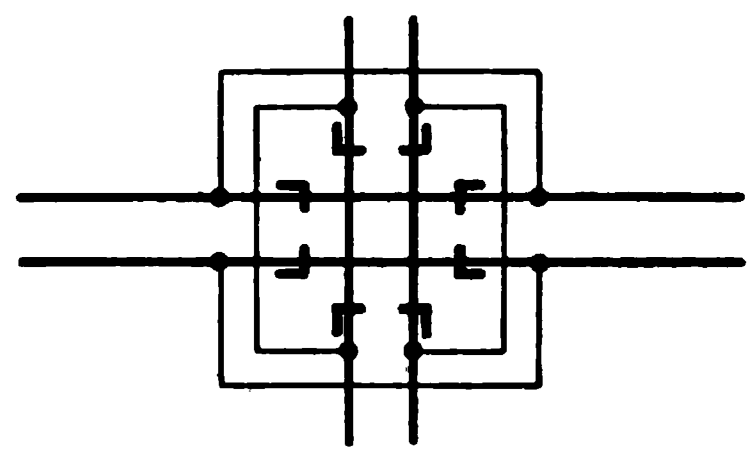

Fig. 134

the frogs. It will be noted that the length A is *cut out,* that is, it constitutes a *dead section* and to make it as short as possible, the circuit is *transposed* (compare with Fig. 133), that is, the polarity of the rails changed, the current of one rail being carried through the jumper and that of the other rail, through the frogs. In Fig. 132 there are circuits on both tracks, one being cut out and passing through the two jumpers, while the other is carried through the frogs. In Figs. 133-134, there are circuits on both tracks and both are cut out, having a dead section through the frog. In one case *one side* of one circuit is carried through the frogs and in the other no current passes through them.

240. Ballast Resistance at Frogs and Switches: The presence of switches or frogs tends to reduce the ballast resis-

tance of a track circuit. This is due to two causes: Rails of opposite polarity occur closer together than in the ordinary track, and insulated rail joints are placed between rail lengths having opposite polarity. In either case, the length of the gap which has to be spanned by the leakage is considerably reduced, and its resistance is reduced accordingly.

SPECIAL CIRCUITS

241. It sometimes becomes convenient to operate one track circuit within another. One method used for this purpose is shown in Fig. 135. In this case, a normally open circuit is in-

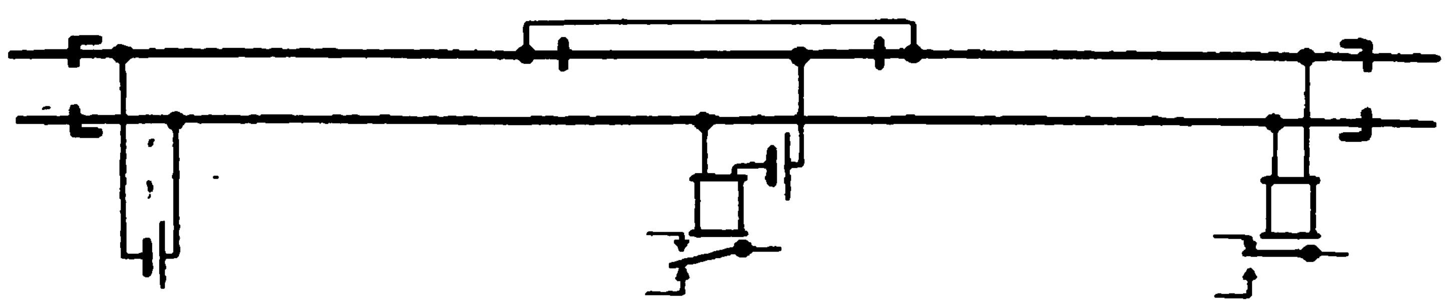

Fig. 135

serted within a normally closed circuit, one rail being common to both circuits. Any wheels in the normally open circuit have no effect on the other relay.

242. Two normally closed circuits, one within the other, are shown in Fig. 136. The jumpers of the longer circuit are cut

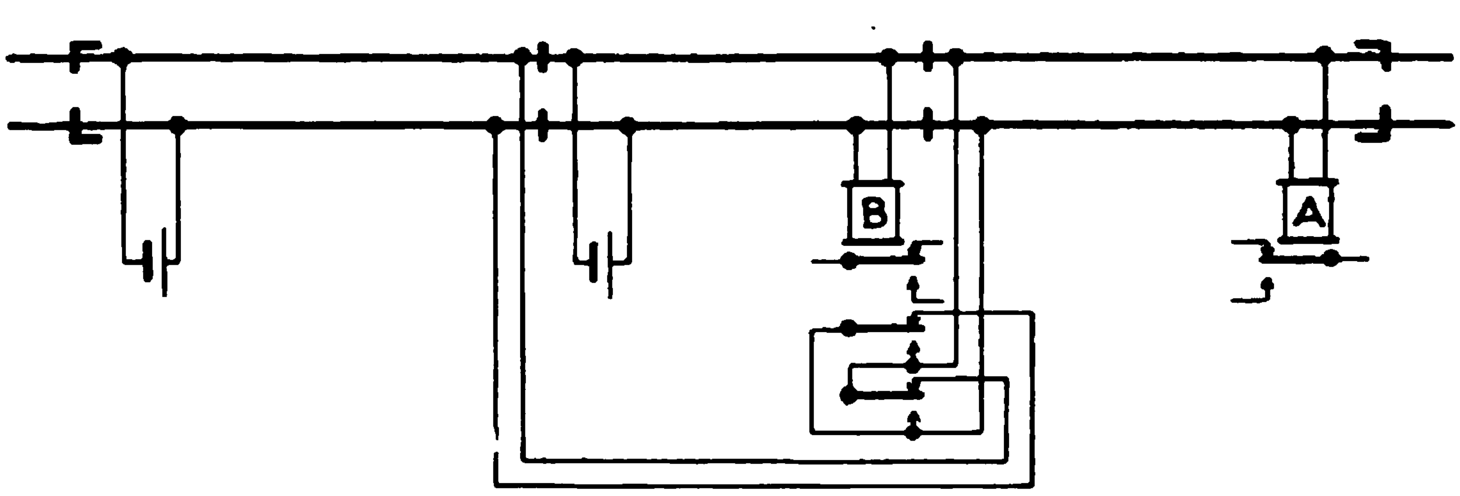

Fig. 136

through front contacts in relay B, which also shunts its relay A through back contacts. Thus relay A will be de-energized by wheels in any part of either circuit.

SUMMARY

243. When considering any track circuit arrangement it is necessary not only to provide for *safe operation* under *ordinary* conditions, but under *exceptional* conditions which, although they may occur very seldom in practice, are *liable* to occur at any time. The possible effects of battery failures, disconnected or broken wires, crossed wires, broken rails, defective insulation or bonding, poor wheel contact, low ballast resistance, etc., must be taken into account and the circuits arranged, if possible, so that any resulting failure will be on the side of safety, and will attract attention so that the proper measures may be taken to remedy the defect and to guard against accident.

EXAMINATION QUESTIONS AND PROBLEMS

(1) What is a normally closed track circuit?

(2) Name an arrangement in which the contact points of a relay forms part of a track circuit.

(3) Define the term *ballast resistance.*

NOTE.—In problems (4) to (7) inclusive, the following conditions are assumed for normally closed track circuits; effective E. M. F. of one cell of gravity battery, 1.07 volts; internal resistance of same, 1.5 ohms; resistance of relay, 4 ohms; ballast resistance, 16 ohms; and resistance of wheel shunt, .02 ohm.

(4) With the track unoccupied: (*a*) What current will pass through the relay if the battery consists of 2 cells connected in multiple? (*b*) What will be the current output from the battery?

(5) With the track occupied: (*a*) What current will pass through the relay with battery arrangement H, Fig. 88? (*b*) What will be the current output from the battery?

(6) With a current output from the battery of 260 milamperes, what current will pass through the relay, when the track is unoccupied?

(7) With a current output from the battery of 1,500 milamperes, what current will pass through the relay, when the track is occupied by a train?

(8) Name two types of battery cells applicable to normally closed track circuits.

(9) For what purpose are track circuits provided?

(10) What is a single rail track circuit?

(11) Using track battery charts Figs. 89-92 in calculating for normally closed track circuits: (*a*) What will be the current through a 5-ohm relay with battery arrangement C, Fig. 88, when the ballast resistance is 1.1 ohms? (*b*) What through a 9-ohm relay, with battery arrangement B, and a ballast resistance of 4 ohms?

(12) What is the object of inserting fuses in the leads of storage batteries used on track circuits?

(13) What would be the result if a storage battery were connected into a track circuit without artificial resistance, assuming that there is practically no resistance in the battery leads?

(14) Why are relayed track circuits used?

(15) What is a polarized track circuit?

(16) On a certain normally closed track circuit the minimum ballast resistance is estimated to be .9 ohm. What artificial resistance will it be necessary to insert in series with a 6-volt storage battery, to insure a 15% working margin for a 5-ohm relay?

(17) (*a*) Which relay used with normally closed track circuits, 3½ or 9-ohm, is more likely to release in case of poor wheel contact? (*b*) Which in case of a broken rail?

(18) Using a 16-ohm multiple clearing relay in connection with a 4-ohm relay, what current will pass through the 16-ohm relay with the track unoccupied, if $E = 1.8$ volts; $b = 1.4$ ohms; and the ballast resistance, 22 ohms.

(19) What is a normally open track circuit?

(20) Assuming the following values for a normally open track circuit; $E = .8$ volt; $b = .03$ ohm; $n = 40$ ohms; $r = 3\frac{1}{2}$

ohms; $s = .06$ ohm. (*a*) What current will pass through the relay when the track is occupied? (*b*) What when unoccupied?

(21) On a certain normally open track circuit, the minimum ballast resistance of which is estimated to be 25 ohms, it is desired to use a 4-ohm relay allowing a working margin of 10%. If the minimum internal resistance of the battery is estimated to be .18 ohms, what is the maximum effective E. M. F. which may be used?

(22) On a certain track, on which it is desired to install a normally open track circuit, the minimum ballast resistance is estimated to be 4 ohms per 1,000 ft. What is the maximum length of circuit which can be operated with a 3½ ohm relay and a battery whose maximum effective E. M. F. is .75 volt, and whose minimum internal resistance is .02 ohm, allowing a working margin of 12½% below the drop-away current of the relay?

(23) What is the meaning of the term *dead track*?

(24) What effect would a break in jumper B, Fig. 129, tend to produce upon the relay?

(25) What would be the effect of a battery failure upon the relay of a normally open track circuit?

(26) What effect would a breakdown of switch rod insulation tend to produce upon the relay of a normally closed track circuit?

(27) What types of batteries are most suitable for use with the differential clearing relay circuit, Fig. 121?

(28) What would be the probable effect produced upon the relay if the insulation broke down in joints C or D, Fig. 122, assuming this arrangement formed part of a normally closed track circuit?

(29) If a portion of the rail between joint D and the frog, Fig. 129, is removed; what effect will it have upon the relay?

(30) If the insulation in joint C, Fig. 129, breaks down; what effect will it have upon the relay?

ANSWERS TO EXAMINATION PROBLEMS

(1) ?

(2) ?

(3) ?

(4) (*a*) 216.7 mil-amp. (*b*) 270.9 mil-amp.

(5) (*a*) 7 mil-amp. (*b*) 1,408 mil-amp.

(6) 208 mil-amp.

(7) 7.5 mil-amp.

(8) to (15) ?

(16) 13.7 ohms.

(17) ?

(18) 74.9 mil-amp.

(19) ?

(20) (*a*) 222.8 mil-amp. (*b*) 18.4 mil-amp.

(21) .787 volt.

(22) 171.9 ft.

(23) to (30) ?

INSTALLATION AND MAINTENANCE

TRACK CONDITIONS

244. One of the first points to be considered in the installation of track circuits, is the general condition of the track. As the maximum length of circuit which it is possible to operate, depends upon the ballast resistance of the track, it is necessary to consider the character and condition of the ties and ballast, and also the drainage.

245. Ties: The principal consideration in regard to the ties, is the amount of moisture which they contain. If they are of thoroughly seasoned wood, and the weather conditions frequently permit them to become well dried, they may be counted upon to assist in maintaining a high ballast resistance, as dry wood is a fairly good insulator. However, such a condition is, perhaps, rather the exception than the rule. Green (unseasoned) ties are often used, and of course, on account of exposure to the weather and from other sources, all ties are subject to more or less wetting. Brine dripping from refrigerator cars on to the ties, increases considerably their conductivity. The kind of ballast used should also be considered; that is, with clean stone ballast the water has a better opportunity to drain away from the ties, than with closely packed ballast such as clay, etc. In many cuts and tunnels the ties seldom or never become very dry.

Chemically treated ties produce a marked effect upon the operation of track circuits, usually tending to lower the ballast resistance. This is especially noticeable in the case of ties treated by the zinc chloride process, although the effect is rapidly diminished by the electrolytic action of the current and the consequent insulating effect around the spikes on the positive rail. In some instances it has been thought that the ties act as a crude form of storage battery, producing current in the rails after the battery is disconnected.

246. Ballast: As in the case of the ties, the amount of moisture contained in the ballast is an important consideration. Aside from this, however, is the conductivity of the material of which the ballast is composed.

The various kinds of ballast are described in the order of their relative values for track circuit purposes, as follows.

247. *Stone. Clean crushed stone* may be considered the best kind of ballast. Its large voids provide good drainage, and its high electrical resistance prevents current from passing through the material.

248. *Gravel.* The insulation resistance of this material is good, but the voids are usually smaller than in crushed stone, and thus less space is left for drainage. Much of the gravel used contains sand which tends to fill the voids.

249. *Sand.* Sand ballast, while it readily allows water to soak through it, when dry blows about and lodges under the rails requiring more attention to keep it cleared from them, than stone or gravel. The insulation resistance of sand, when dry, is fairly good.

250. *Loam and Clay.* Loam and clay retain a large amount of moisture. Loam when dry forms dust which lodges under the rail, and both materials when wet, tend to work up around the rails, or in other words, they "puddle", and thus allow the track to settle into them.

251. *Cinders.* Probably the worst kind of ballast usually found in practice is that composed of locomotive cinders, which, although they contain a fair percentage of voids, thus allowing water to soak away, are frequently made up of a large percentage of carbon, thus forming a fairly good conductor. Much of this carbon is in the form of coke which, being light, is blown and lodges beneath the rails, materially lowering the ballast resistance.

252. From the foregoing it is evident that in order to secure good results, the ballast if in contact with the rails,

should be well cleared from them, before attempting to operate the circuit.

253. In many tunnels the ballast resistance is low, as, although the drainage is frequently good, the water dripping from the roof generally keeps the ties and ballast saturated. In addition, practically all of the locomotive sparks (composed principally of carbon) settle upon the road-bed, thus lowering somewhat, the ballast resistance.

When ballast freezes its resistance usually increases and therefore trouble may be experienced on circuits installed in cold weather, due to the lowering of this resistance when the ballast begins to thaw out.

254. Drainage: The standard road-bed of most railroads is generally designed with a view of securing good drainage, but occasionally conditions are found, especially in yards and sometimes in cuts, where the drainage is poor, water being allowed to collect and stand around the rails. This condition should be remedied, as circuits cannot be expected to operate in a reliable manner under such circumstances.

255. Highway Grade Crossings* and Station Platforms: A highway grade crossing ordinarily constitutes a weak point in a track circuit for several reasons.** Frequently drainage from the highway runs on to the track, while the opportunity for securing good drainage from the track is usually not as good at the crossing as on the regular road-bed. The planking prevents the sun and free circulation of air from reaching the ties and ballast in the crossing, which receive and thus retain a large amount of moisture.

256. Station platforms, in which the track is planked, present a condition similar to the highway grade crossing, but in this case, water is seldom drained on to the track, and as the planks are usually somewhat thinner than in the crossing, and frequently laid with a small space between them, a better circulation of air is provided about the ties and ballast, which produces a dryer condition.

*All types of planked crossings.

**Other reasons are given under Bonding, Art. 295.

257. In some cases the space between the rails at crossings and platforms is filled with small crushed stone or gravel. This of course has a greater tendency to keep the ties and ballast in a moist condition than where planking is used entirely.

From the foregoing it is obvious that the ballast resistance of a length of track having a number of highway grade crossings or a considerable length of station platform of the type described, may be expected to have a lower ballast resistance than would otherwise be the case.

258. Bridges and Structures*: As *unballasted* bridges and structures are usually well drained and ventilated, water is not likely to penetrate the ties (or timber to which the rails are secured). If the structure is built principally of *wood,* the resistance from rail to rail is likely to be quite high. Again, if the main part of the structure is of *steel,* and the rails are laid on ties, or timbers, which are entirely above the girders upon which they rest, so that no portion of the steelwork comes nearer to the rails than the depth of the ties, a good insulation resistance will usually be obtained.

259. However it sometimes happens that portions of the steelwork extend up between the ties. As the ties become worn they allow the rails to come so close to the rivet heads, etc., that in wet weather the space between is spanned by water, and as the rest of the path (formed by the steel structure) is, of course, a very good conductor, the resistance between the rails is greatly reduced. In such instances this condition must be improved before the circuit will operate properly. To do this, new ties should be installed, but in case this method is impracticable, the rails may be raised by the use of ½ in. boards, commonly known as *shims.*

260. In some types of construction the rails are laid directly upon the steel flooring, in which case it is necessary to insulate them from the structure; this is usually accomplished by a suitable application of vulcanized fiber.

*Arch bridges, on which the ballast arrangement is the same as on ordinary track, are of course not considered in this connection.

261. On *ballasted* steel structures the insulation resistance between the rails is usually rather low, on account of the small amount of ballast used and the consequent proximity of the rails to the steelwork.

262. Maintenance: Occasional inspection of the track is necessary. Ballast tends to collect about the rails, and in some instances lowers the resistance between them. The drainage should also be observed, and not allowed to become defective. Unless these matters are given proper attention, the ballast resistance of the track will gradually be lowered, and failures are apt to result.

263. Another point to be considered is, that if the ballast is allowed to come into contact with the rails, it will, in some cases, reduce the efficiency of the circuit to detect broken rails, on account of the path which the ballast provides, around a break in the rail.

264. If in renewing, a large number of green ties are installed, the insulation resistance between the rails will be considerably reduced. If this reduction is sufficient to affect the operation of the relay, it must be overcome by increasing the battery power. In tunnels and at other points where the ballast resistance gradually becomes lowered due to damp conditions, the effect thus produced, may be remedied in a similar manner. However, if the practicable limit of battery power is reached without securing the proper operation of the relay, either dry ties should be installed, or the track circuit shortened, by relaying (Art. 169), or otherwise. Where it is not desired to use either of these methods, temporary relief may be obtained by pouring oil* around the base of the rails, this tending to insulate them from the ties and ballast.

265. On steel structures where the ties rest upon girders, which are frequently located beneath the rails, failures are sometimes caused by *long* spikes being driven through the ties, making connection between the rails and the structure.

*Cheap black oil is generally used.

BONDING

266. Drilling: One of the most important features in connection with the installation of track circuits is a practical method for drilling the necessary holes through the rails, in which to secure the bond wires.

For this work there have been designed several types of special track drilling machines, most common among which are the *Wilson track drill,* Figs. 137-138, and the *Union track drill,* Figs. 139-140. The principal advantage of the Wilson machine is its self-feeding feature, while the advantage of the Union machine is the fact, that it may be used for drilling holes, not only in the *web,* but also in the *base* of the rail; the latter provision being necessary when installing the *plug bond,* as shown in Fig. 6.

Care should be taken that the holes are drilled completely through the rail, leaving no burr to interfere, when driving the channel pins or plugs.

267. The Wilson Track Drill-

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is

or

d

better bearing for the set screw.

Fig. 138

The machine is placed upon the rail as illustrated in Fig. 137, first running the spindle as far back as it will go and placing the toggle lever at the back of the machine, in its lower position as shown. Care should be taken that the ends of *both* hooks bear against the rail, in order that the hole will be drilled straight through the web. The base of the machine must stand firm and square on the ties so that the hooks will rest evenly on the top of the rail. Unless these precautions are taken, the strain on the drill will cause it to run hard and heat up, and will frequently result in breaking it. To steady the machine, one foot is placed upon the half circle foot plate. The toggle lever is then raised as shown in Fig. 138, which carries the sliding frame forward and brings the drill close to the rail. The *driving* of the drill spindle is performed by the forward (nearest the rail) set of gears, the large wheel of which is mounted loosely on the crank shaft, and the *feeding* by the other set. The drill point should now be moved into contact with the web of the rail by holding the forward sprocket wheel, and revolving the crank. When the drill point presses against the rail, the pawl or latch, which is pivoted to the crank shaft, is moved into engagement with one of the spokes of the forward wheel, causing it to turn with the crank.

After the hole is drilled, unless it is desired to remove the machine quickly, it should be fed back until the drill clears the hole, before the toggle lever is thrown back. This will gauge the position of the spindle for the next hole to be drilled.

At certain points, such as bridges and structures, it is sometimes impossible to use this type of drilling machine, on account of the interference of guard rails and guard timbers.

268. *The Union Track Drilling Machine,* (Figs. 139-140). This machine is clamped to the head of the rail by pressing down the lever, shown extending to the right in the illustrations, the clamp being adjustable, so that it may be fitted to any size of rail. As will be seen, the spindle is driven by the crank at the side of the machine, through bevel gears, the feed being controlled by the handle at the end of the machine. Considerable care must be exercised in feeding when the drill point is breaking through, as if fed too fast, the drill will

be required to cut more metal than it will ordinarily stand, and may in consequence be broken. After the hole has been drilled

st be fed back, withdrawing
f the hole, before the clamp-
ised, otherwise the drill is
ken. A $\frac{15}{64}$ in. round shank
rily used when drilling for

s a wide diversity of opinion
ise of oil or drilling solution
point. Much *dry* drilling
is requires more labor and
erably the life of the drills.
tly used, being very satisfactory for drilling purposes, but as it is a non-conductor it is thought that the oil remaining in the joint when completed will reduce its conductivity, although many engineers consider this objection negligable. A solution of salsoda (sodium carbonate crystals)

Fig. 139

and water,* is sometimes employed with good results. Although it has not the lubricating properties of oil, it keeps

*$\frac{1}{2}$ lb. of salsoda to 1 gal. of water (preferably hot when mixing)

the drill cool, is a fairly good conductor and tends to prevent rusting.

270. Care should be taken when drilling near old holes or near the edge of the rail base, that a sufficient distance is provided to insure, that when the pin or plug is driven, the hole will not spread. Between the edge of the rail and the hole, at least $\frac{3}{8}$ in. of metal should be allowed.

271. *Drill Grinding.* In order to secure good results the drills should be accurately ground. As it is very difficult to do this when the drill is held by hand, this method should be employed only when other means are not available.

The principal part of one type of drill grinding machine is shown in Fig. 141. It will be noted that the drill is held in position for grinding by a pivoted frame, adjustable to any length of drill. As the emery wheel is revolved, this frame is moved back and forth upon its pivot, thus drawing the drill point across the face of the wheel, and grinding one lip of the drill. This operation is repeated on the opposite lip, care being taken that both lips are ground alike; if ground one-sided it will probably drill too large a hole. This type of machine is arranged to be operated either by hand, or by power.

Fig. 141

Where many drils are used they are generally sharpened on a power grinder, this method giving the best results.

272. Applying Bond Wires: Two methods of applying bond wires, by means of *channel pins* or *bonding tubes,* are shown in Figs. 142-143. It will be observed that *two* bond wires are installed at each joint, the object of this arrangement being, that in case one should become broken or otherwise deranged, the other will still be effective to maintain good conductivity around the joint.

273. Although in the illustrations the wires are shown *outside* of the angle bars, they are sometimes located *inside*. The use

Fig. 142

of copper or copper clad steel bond wires behind splice plates is permissable, but iron wires should not be so placed as they will

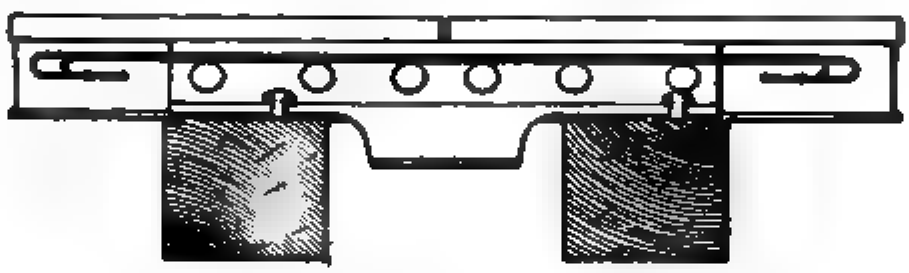

Fig. 143

rust quickly and on account of the difficulty of inspection are very likely to become a source of trouble.

Bond wires are usually placed on the gauge side of the rail, but in some cases one wire is placed on each side.

274. In tunnels and at highway grade crossings and station platforms the following is recommended practice: At joints in tunnels, copper or copper clad steel wire should be used. At joints in highway crossings and station platforms two iron or copper clad wires should be used on the gauge side of the rail, and also two copper or copper clad wires outside of the rail, the latter being a protection in case the wires on the gauge side of the rail should be broken when removing ice, etc., from the flangeways. The copper or copper clad wires are used at these points on account of the corroding effect which water, etc., has upon iron.

The spacing of the holes for bonding, varies on different roads, dimension A, Fig. 142 being from 2½ in. to 3 in. and dimension B, from 2 in. to 3 in. These dimensions need not be followed with a great degree of accuracy as the exact position of the holes is not a matter of extreme importance. Of course, the nearer to the end of the rail that the bonds are attached, the greater the

amount of broken rail protection provided, (Art. 122), the spacing given being desirable for convenience in applying and maintaining the bonds.

275. A method of applying the *plug* bond to the base of the rail, is shown in Fig. 144. Dimensions A and B are the same

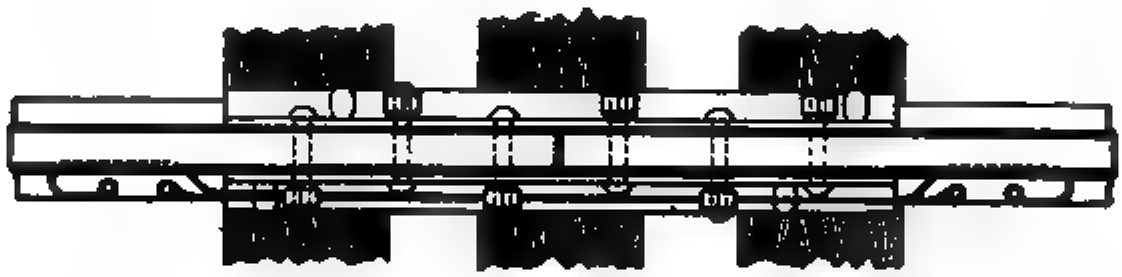

Fig. 144

as those given in connection with Fig. 142, although they will be varied on account of the necessity for keeping the bond terminals well clear of the spike heads, as the creeping of the rails is likely to bring them into contact and result in damaging the terminals.

276. It will be noted in the illustrations that the wires are not stretched tightly along the joints, considerable slack being allowed. This slack is necessary first, because of the expansion of the rails, second, because it assists in overcoming the vibration from passing trains which tends to break the wires where they are attached to the rails, and third, to permit the renewal of the splice plates, without disconnecting the bond wires. That portion of the wire, in Figs. 143-144, extending beyond the terminal, is known as an *expansion loop.*

277. When using *channel pins* or *bonding tubes,* for attaching bond wires, the following method of procedure will give satisfactory results. Before attaching the bond wires, the condition of the ends should be noted; that is, whether or not the parts of the wire which come into contact with the pins or tubes, are clean, any corrosion or other foreign substance being re-

moved by the use of emery cloth or sand paper. Dirt sometimes lodges within the bonding tubes, which should be removed before they are used.

The next step is to make a right angle bend at one end of the wire*, being careful, in the case of iron wire, that when so doing, the bend is not made too sharp, as it would be likely to crack the galvanizing, causing it to flake off. If the wire is to be put between the splice plate and the rail, it should now be pushed into position. The end of the wire which has been bent, is now passed through the hole and a pin or tube is placed upon it with the large end flush with the end of the wire, after which both are pushed back into the hole and driven home, as nearly flush with the rail as possible. A strong mechanical joint and a good electrical connection are thus obtained, on account of the compression which takes place, owing to the combined cross-sectional area of the pin and wire being *greater* than that of the hole.

The wire is now formed into its permanent shape, first at the end already secured and then at the opposite end, finally making a right angle turn directly opposite the hole in which it is to be secured. This end is now bonded into the rail in the manner just described, thus completing the bond.

Care should be taken, that the wires be placed in their proper holes; for instance, the wire, one end of which is fastened in hole C, Fig. 142, is secured at the other end, in hole D.

278. Some engineers advocate the dipping of channel pins in oil, the lubricating effect permitting the pin to be more readily driven. Others object to this practice on account of the insulating effect of the oil.

279. Channel pins are sometimes used in attaching bond wires to the base of the rail. When so applied the channel pin must of course, be driven from the side of the rail on which the wire extends, and therefore the ***channel pin set*** shown in Fig. 145, is employed, the groove fitting over the wire.

Fig. 145

*The distance from the end of the wire to the turn, is governed by the permanent shape which the wire is to have.

280. The method of applying the *plug bonds* shown in Fig. 144, will now be described. As the wire is soldered to the plug at the factory, the next step, after drilling the hole, is to make the attachment to the rail. The first plug should be driven in one of the holes next to the splice plate, being careful that when starting to drive it, its axis is in line with that of the hole. The plug should be driven to the shoulder, care being taken that the hammer does not strike the edge of the head or the wire, as it will probably break the solder, thus loosening the joint and ruining the bond. The wire is now bent into its permanent form and the other plug driven. As before noted the diameter of the hole is $\frac{15}{64}$ in., while that of the plug is $\frac{1}{4}$ in., thus a *driving fit* is secured, making a good mechanical and electrical connection.

281. It is ordinarily not feasible to install this type of bond behind the splice plates, as it generally requires their removal to do so, on account of the plugs being soldered to the bond wires.

282. Plug bonds are sometimes attached to the web instead of the base of the rail. Although somewhat more difficult to drive they are free from interference with spikes.

283. A 2 lb. machinists' hammer is generally used when bonding. A lighter hammer, on account of the greater number of blows necessary, batters up the heads of the pins or plugs, while a heavier hammer is likely to buckle or bend them.

284. It is very desirable that the holes be *plugged** the same day that they are drilled, as the bright surface of the steel inside the hole oxidizes (rusts) rapidly when exposed to the action of the atmosphere. As iron rust is a poor conductor, its presence greatly reduces the conductivity of the bond. If for any reason holes cannot be plugged the same day, they should be protected against rusting, by the use of oil, vaseline, etc. When ready to plug the drill should again be run through them.

Holes that have become badly rusted, owing to their remain-

*This is a general term indicating the attaching of bond wires by means of channel pins, bonding tubes or plugs.

ing unplugged for a considerable length of time, should not be used.

285. In case a channel pin or bonding tube is poorly driven, it can be removed with the aid of the punch shown in Fig. 146, first cutting off the bond wire. If for any reason it is desired to remove a plug, the head should first be broken off, by striking it a sharp blow on the side, after which the stub is driven out with the punch.

Fig. 146

286. *Bonding at Switches and Frogs.* At points in track circuits where switches and frogs occur, special bonding conditions arise. In Fig. 147 is illustrated a common arrangement

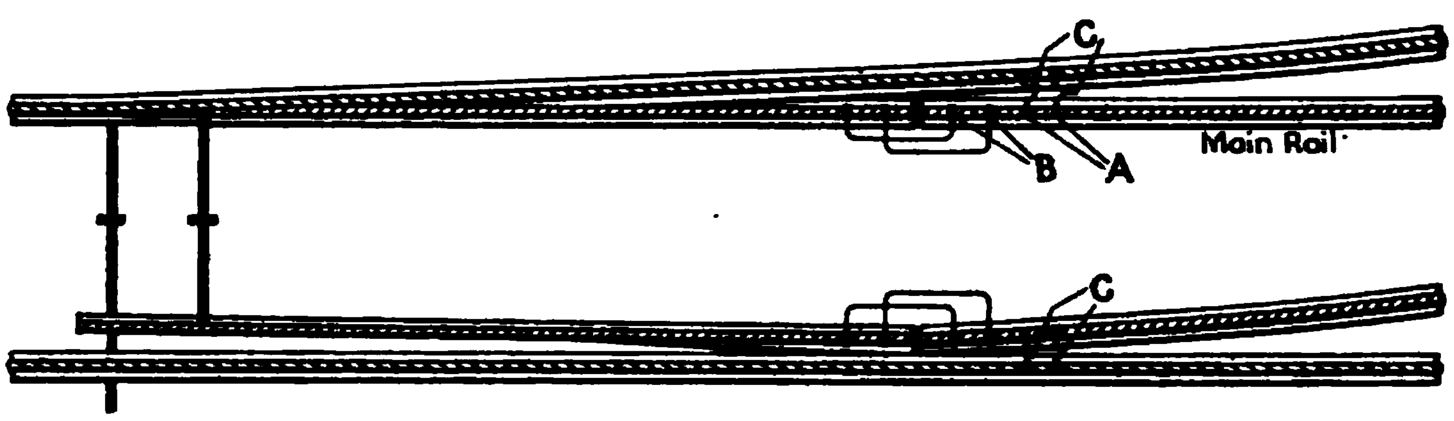

Fig. 147

of bonds at switches. Terminals A should be as close to terminals B, as it is convenient to place them, in order to have as much of the main rail *in series* as practicable. Bond wires C, are frequently stapled to the ties, to keep them out of the way.

Where the reinforcing of switch points interferes with bonding into the web of the rail, the bond wires must be attached to the base.

287. Although frogs are bolted or riveted together they can-

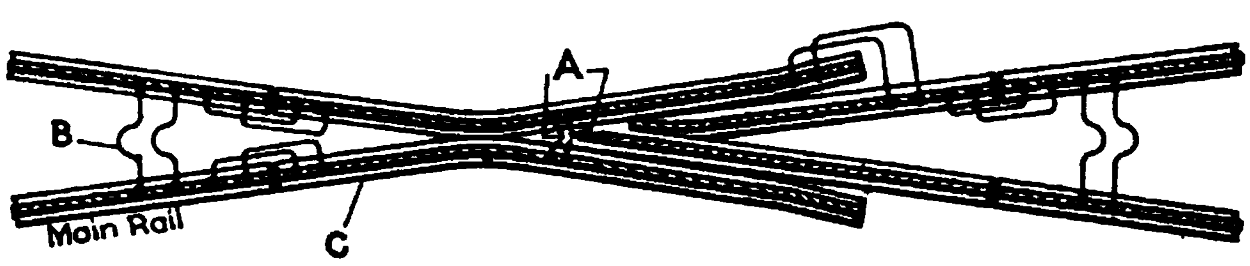

Fig. 148

not be depended upon to produce a good path for the current; it is therefore necessary to bond them. In Fig. 148 is shown

a method for bonding at frogs. Where space permits, bond wires A are sometimes installed in rigid frogs, instead of wires B, in which case main rail C is placed in series; thus broken rail protection is secured for this length of rail.

On account of the different sizes of frogs and the various practices prevailing, several other arrangements of bonds may be used to advantage. However, in all cases the bonding should be such, that it will be impossible to remove the frog without breaking the circuit.

288. An arrangement for bonding at derails is shown in Fig. 149.

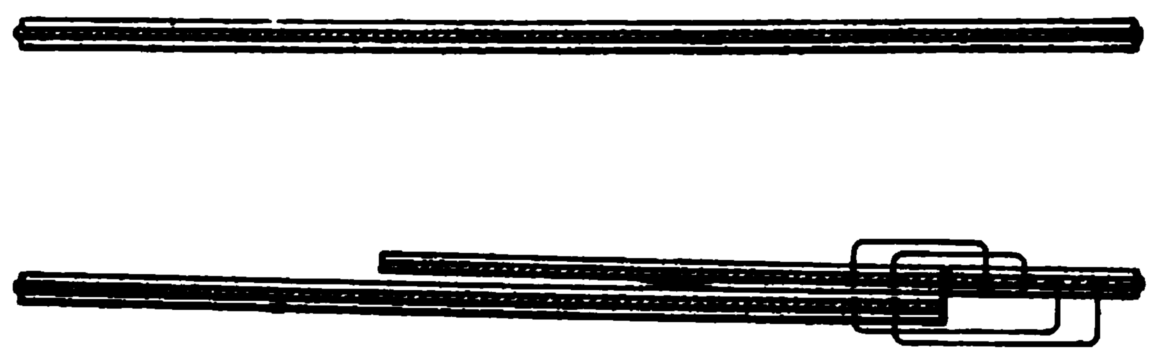

Fig. 149

289. Occasionally at switches and derails and especially at frogs it is often desirable to use bond wires longer than those required at the ordinary joints. In such instances, to secure greater strength and also to produce a neater appearance, these long bond wires, or jumpers, are frequently twisted together and are sometimes stapled to the ties.

290. As it is frequently necessary, at switches, frogs and guard rails, to drive channel pins from the side of the rail on which the wire extends, the channel pin set, Fig. 145, can be used to advantage.

291. The jumper wires should if possible be kept from under the wooden blocking or foot-guards, occurring at frogs, switches, etc., on account of the difficulty of inspection if placed beneath them.

292. Maintenance: Frequent inspection of bond wires is necessary. Vibration due to passing trains sometimes causes them to break. The expansion and contraction of the rails often

bows the wires, forcing them into such a position, that upon the passing of a train they will be caught under the spike heads and damaged. It is the practice on some roads to overcome this by driving the spikes reversed, that is with the back of the spikes towards the splice plate, as shown in Fig. 142. As copper is softer than iron, bonds of this material are more apt, in such instances, to be cut by the spikes. When the bonds are attached to the base of the rail, care must be taken to see that spikes are not driven too close to the terminals, (Art. 275), while in some cases, either the spikes have to be moved or the bonds renewed owing to excessive creeping of the rails.

293. Bond wires are frequently injured or broken by trackmen working about the rails; for instance, when renewing bolts or splice plates, a bond wire may be pinched under a splice plate or bolt head, and when located inside the splice plates. may be accidentally cut off when driving in a new bolt. When renewing ties, and when surfacing or shimming track, etc., the wires are often damaged by the tools employed.

294. Where a large number of refrigerator cars pass over the track, the salt water dripping from them, causes iron rail bonds to rust quickly.

295. One of the most difficult points at which to maintain bond wires is at highway grade crossings. First, on account of the comparatively damp condition, the wires are subject to a great deal of corrosion; second, they are difficult to inspect: third, as before noted, they are often damaged when picking ice from the flangeways; and finally, salt placed in the flangeways to keep them clear of ice, adds greatly to the corroding effect.

296. At frogs and switches the renewal of ties and of the wooden blocking. sometimes results in damage to the jumper wires. Also the use of salt, to keep the switches, frogs and guard rails free from ice, tends to corrode the bonds.

297. At points, such as bridges, structures, fills, etc., where long guard rails are in use, the bond wires should not come

into contact with them. If allowed to do so they will be likely to interfere with the operation of the circuits; for instance, the guard rails are often brought together at the ends, as shown in Fig. 150, in which case, the relay might be shunted, if bond wires, as at A and B, come into contact with them. In other instances, where the guard rails span two circuits, and are not joined at the ends, as in Fig. 151, current from battery A of one circuit might energize relay B of the other, owing to

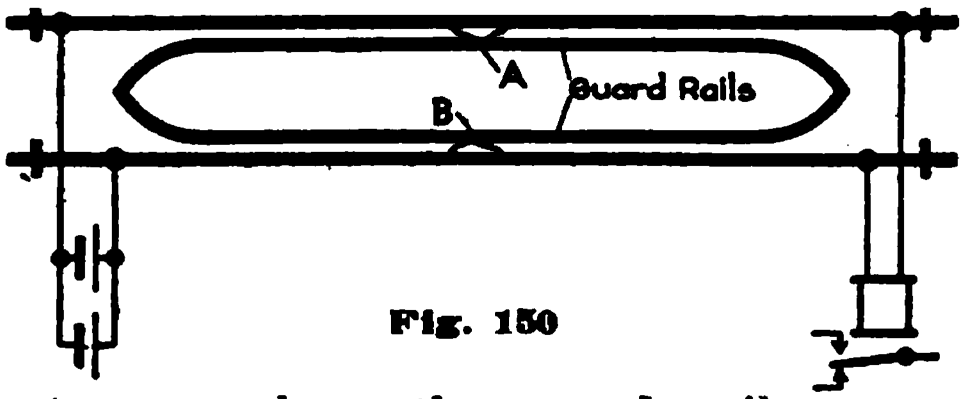

Fig. 150

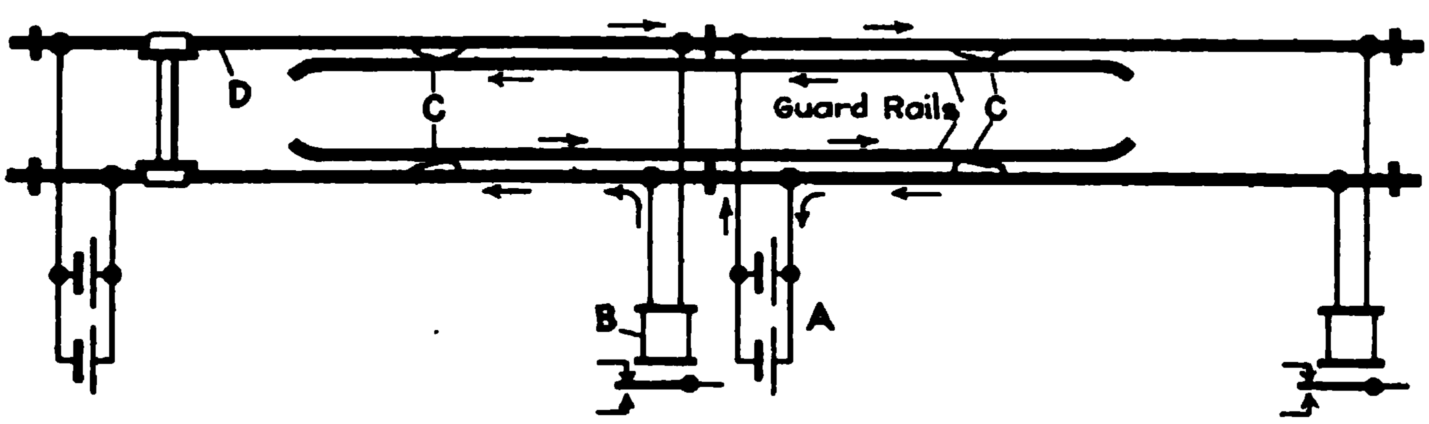

Fig. 151

the bond wires C, touching the guard rails and thus forming a path around the insulated joints as indicated by the arrows. If the circuits are otherwise in good order, they will operate as usual and thus such a condition remain undiscovered; but in the event of defective bonding or a broken rail, for example, at point D, relay B would be energized by battery A, with a train occupying the position shown, thus producing a very dangerous condition.

298. When renewing rail bonds, it is not advisable to remove old channel pins or bonding tubes, with a view of using the same holes. The labor involved in so doing, is usually greater than that required to drill new holes, and further the results obtained are generally not so good. With the plug bond, the old holes are often used to advantage.

When removing defective bonds, they should be cut off close to the rail, a cold chisel being useful for this purpose.

INSULATED RAIL JOINTS

299. It is the practice on many railroads to have the insulated rail joints installed and maintained by the track department, under the supervision of the signal department. On account of such supervision, it is necessary that the signal forces be familiar with the proper method of procedure.

The insulated rail joints separating two adjacent double rail track circuits, should be located as nearly opposite as possible, although it is not necessary to cut rails to do this, except where the joints are so far apart that the resulting dead section would be long enough to contain a car or engine without shunting either circuit.

300. Installation: As the installation of an insulated rail joint renders the track temporarily unsafe for the passage of a train, on account of the removal of the splice plates, it is necessary before beginning the work to take the proper precautions, which generally requires the putting out of a flag.

301. Unless absolutely necessary insulated rail joints should not be installed at the end of a rail that has been cut with a *track chisel,** on account of rapid wear that such an end will produce on the *fiber end post.* In any case such a joint should not be allowed to remain in service, a rail having a *sawed* end, being substituted as soon as possible. If, however, it is necessary to install such a joint as a temporary arrangement, the rough parts of the chiseled end should be trimmed off with a cold chisel and all sharp edges battered down with a hammer. As in many cases only one end of a length of rail is chiseled, it may be turned end for end to produce the desired results.

302. If owing to expansion, the rail ends are too close together to readily receive the end posts, care must be exercised that when separating them, they are not battered as is liable to be done, by spreading them with a track chisel, thus producing a surface that will quickly wear through the fiber.

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*Blacksmith's cold chisel.

303. After the regular splice plates have been removed, the bolt holes, if fiber bushings are to be placed in the web of the rail, must be *reamed* to receive them. This is usually done with the aid of a *sleeve ratchet* held in place by a short piece of rail spiked to the ties, or by a *ratchet clamp.**

After the reaming is completed, care must be taken to remove all steel chips, as they are liable to bridge some part of the fiber insulation, and thus allow current to pass through the joint.

304. Where portions of the insulated joint extend between the rail base and the ties, the ties have to be dapped with an adz to receive them.

305. The next step is to put the joint in place, being careful to insure that all fiber parts are in their proper position. If the bolts cannot be easily pushed into place, they should *not* be driven, as it is very likely to injure the fiber bushings and washers. If the bolt holes do not align properly, the trouble is generally caused by the contraction of the rails, which may be remedied by bringing the rail ends closer together and thus aligning the bolt holes.

306. Maintenance: The insulated rail joint performs an important function in connection with the track circuit, and therefore frequent inspection is very desirable. As the insulating parts are constantly compressing it is often necessary to tighten the bolts. It is also imperative that the joint be well supported. If these matters are neglected, the insulating parts will wear rapidly, with resulting failures.

307. Contraction of the rails will sometimes cause trouble by cutting the fiber bushings, while expansion will frequently so compress the end posts, that the burr which is formed by the wheels at the top of the rails will *bridge* them; thus in either case current is allowed to pass through the joint. The burr on the rail ends should occasionally be removed with a cold chisel, the chip not being permitted to drop into the joint.

*A steel bracket.

308. In damp climates and at points, such as tunnels, etc., where insulated rail joints are subject to a great deal of dampness; the fiber absorbs much moisture and in consequence becomes soft, causing it to wear out quickly, and also lowering considerably, its insulation resistance.

In some cases it is advantageous to coat the fiber insulation with heavy oil or other insulating compound, before the joint is installed, applying additional coats to exposed parts of the fiber at frequent intervals.

309. In rare cases, such as subways, where the traffic is heavy and stations frequent, trouble has been experienced by steel dust from brake shoes, collecting at the joints, so as to span the ends posts. In such instances the joints should be swept regularly.

310. When renewing bolts in insulated joints care must be exercised that the fiber bushings are not damaged, it being remembered that on account of contraction the bolts are often more difficult to put in place, than when originally installed.

311. *Testing.* It is desirable to have some means for testing insulated rail joints while in service, as all the insulating parts cannot be inspected without taking the joint apart. A method used to accomplish this is shown by the diagram, Fig .152, in which one cell of dry battery, a resistance of one ohm, and a milammeter reading to 1,500 milamperes, are employed. The purpose of the one ohm resistance is to protect the meter from injury, in case of extremely low resistance in the joint.

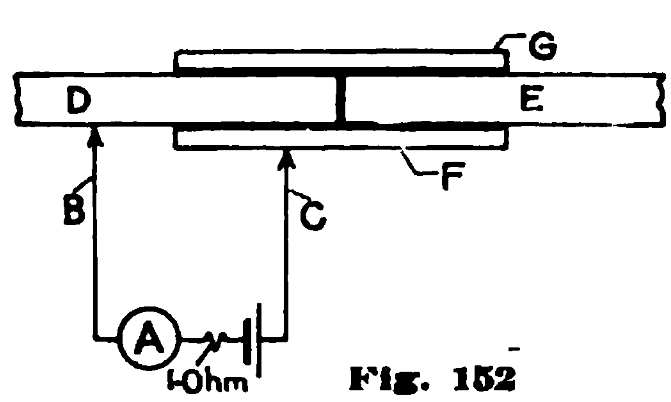


Fig. 152

312. As it is necessary to insure good contact on to the rails and the joint, the common practice is to use small files

Fig. 153

as terminals for wires B and C, so that a clean, bright contact may be readily made. The files are usually arranged as shown in Fig. 153.

313. Assuming that it is desired to ascertain if there is a break-down of insulation in a joint, in which the bolts are insulated from the splice plates and not from the rails, as in Fig. 9, the procedure will be as follows: First, one terminal is connected to rail D, Fig. 152, and the other to splice plate F. If the meter shows no appreciable deflection it indicates that the insulation between these parts is in good condition. The same test should now be made between D and G, E and F, and E and G. If the insulation between these parts is also found to be good, the next step is to test the insulation between the bolts and the splice plates, trying each bolt separately, with each plate.

314. If the bolts are insulated from the rails, but not from the splice plates, as in Fig. 8, the test between the rails and the splice plates is the same, but the test for the bolt insulation must, of course, be made between the bolts and the rails.

315. Owing to leakage on account of moisture a small reading is to be expected, especially where the plates extend beneath the rail, which, although the joint *may not* be defective, will occasionally run as high as 100 mil-amperes. However, if the insulation *is* defective a much higher reading will be obtained.*

316. If it is desired to determine the insulation resistance for any of the foregoing tests it may be done by connecting a low reading voltmeter (0 to 3 volts is a convenient scale), as shown in Fig. 154, and calculating the resistance by the use of Ohm's law.

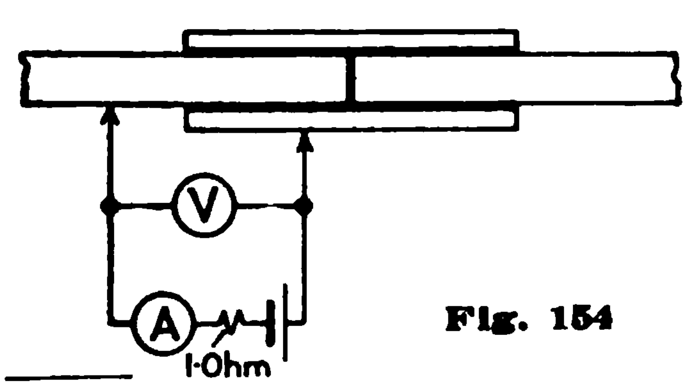


Fig. 154

317. PROBLEMS.—(1) If in Fig. 154, the voltmeter gives a reading of 1.35 volts, and the mil-ammeter a reading of 50 mil-amperes, what is the insulation resistance between the parts tested?

*These figures are based on the assumption that the internal resistance of the dry cell is normal and that it gives an effective E. M. F. of approximately 1.5 volts.

(2) If under the same conditions as in problem (1), the readings are 1.41 volts and 15 mil-amperes, what is the insulation resistance?

Answers.—(1) 27 ohms. (2) 94 ohms.

318. It is evident that the foregoing tests will not indicate whether the end post is effective in preventing the passage of current through the joint. A means of accomplishing this is illustrated in Fig. 155, in which it is desired to test the insul-

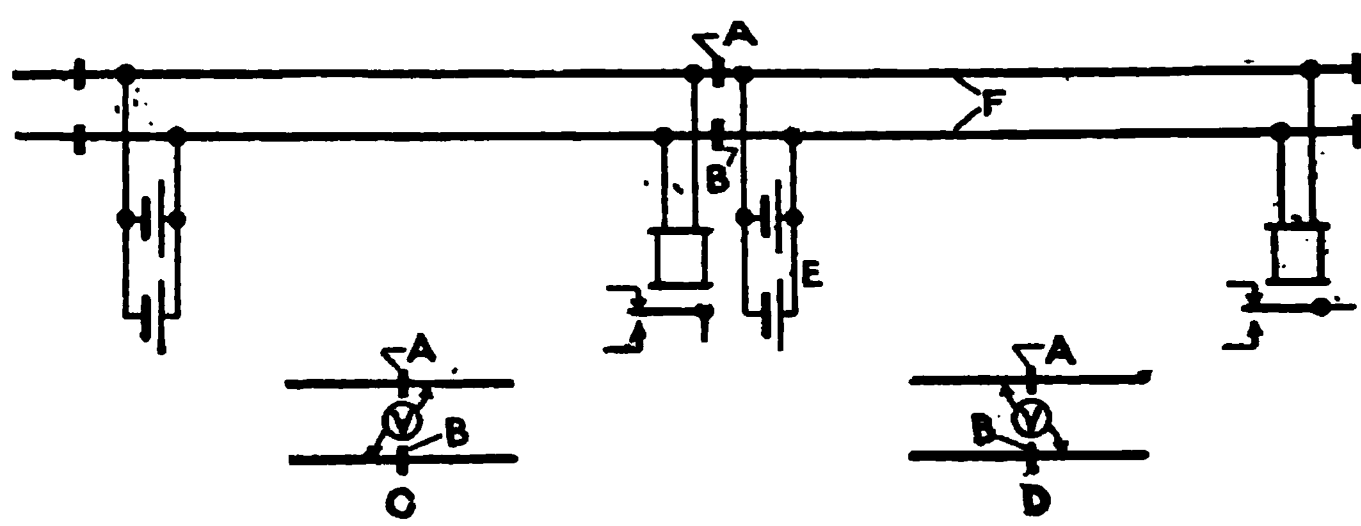


Fig. 155

ation resistance of joints A and B. A low reading voltmeter is connected as shown in sketch C. If there is practically no deflection noted, it will ordinarily indicate that both joints are in good condition; but to insure a reliable test the connections should be reversed as shown in sketch D. If a deflection is noted in either case, the next step is to ascertain which joint is defective, the most convenient method being to disconnect battery E from the track, thus making rails F *dead.* Then, if the reading is obtained with the connections as in sketch C, joint A is at fault, while if obtained when connected as in sketch D, the trouble is in joint B.

319. The test described in Art. 318. cannot be depended upon where there is considerable foreign current, which is frequently the case in the neighborhood of electric railways using direct current for propulsion; as in such instances, the foreign current often produces readings on the meter similar to those that would be obtained if one of the joints were defective.

SWITCH AND PIPE LINE INSULATION

320. Switch Rod Insulation: Switch rods which are to be used in track circuit territory, are frequently insulated when being manufactured. Where this is not the case, or where circuits are being installed on track where uninsulated switches occur, the rods must be insulated, unless some other arrangement such as *wedge blocks* or *cut-outs* (Art. 227), are employed.

321. Before removing the rods, the switch points must be spiked, to prevent interference with traffic.

When removing a switch rod preparatory to insulating it, it is convenient to have a duplicate *adjustable rod,* which may be used as a substitute, so that it will not be necessary for the switch to remain spiked, while the rod is being insulated.

322. When reaming or drilling holes in which insulation is to be placed, all chips must be removed before the insulation is applied.

323. When installing the switch rod insulation shown in Fig. 19, the rod is removed from the track, and the hole reamed to contain the fiber bushing. This is ordinarily done in a drill press using a drill of the same size as the outer diameter of the bushing, the inner diameter of the latter being the same as that of the bolt. Thus a tight fit is secured preventing lost motion in the switch. If necessary the head rod is now offset as shown in Fig. 19. When replacing the rod, if there is not sufficient space in the lug for the fiber washers, it may be spread with the aid of a track chisel.

As the fiber bushing is subject to some wear, occasional inspection is desirable.

324. When insulating switch rods in the manner shown in Figs. 20-22, the splice plates are usually furnished drilled.

Where circumstances permit the insulated joint is placed in the center of the switch rod, although in adjustable switch rods and in rods to which the throw rod is connected, it is generally located to one side. When applied near the end of the rod care

must be taken to insure that the splice plates will not come into contact with the switch lug, as this would bridge part of the insulation.

325. After the switch rod is removed from the track, the position of the bolt holes for the joint is outlined with a scriber, using one of the splice plates as a templet. With these outlines as a guide the rod is marked, with a center punch, for drilling. It is the practice to drill the holes either the same size as the outside diameter of the bushings or $\frac{1}{32}$ in. larger, the holes being slightly chamfered with a larger size drill. The next step is to cut, with a hack saw, $\frac{1}{2}$ in. of metal from the rod at the center of the joint, after which the joint is assembled complete, the bolts being well tightened.

An alternative method is to cut the rod hot before drilling, considerable care being exercised to insure that the distance between the holes in the rod by which it is fastened to the switch lugs, remains the same.

326. Before the switch rod is replaced in the track the insulation resistance of the joint should be tested with a magneto. Of course, the test should be applied not only between the two ends of the switch rod, but also between the rods and the splice plates and bolts.

If a magneto is not available a test may be made with the apparatus used in testing insulated rail joints, Art. 311.

327. Front and Lock Rod Insulation: These rods, types of which are illustrated in Figs. 29-31, are almost invariably insulated at the factory, but if necessary to insulate them on the ground, the procedure is similar to that outlined in connection with switch rods.

328. Wedge Blocks: The method of applying the wedge block is shown in Fig. 32 although instead of two blocks being used, placed on the first and third ties, one attached to the second tie, will in some cases suffice.

Before putting the wedge blocks in place the head rod should be offset, if necessary.

Generally two or more lag screws are used to secure the blocks to the ties, but large wood screws are sometimes employed. The metal wedge blocks must not be allowed to come into contact with the slide plates or the stock rail. To secure sufficient clearance and also to prevent the lag screws from splitting out at the side of the tie it is sometimes desirable to move the slide plates to one side.

329. Frequent inspection is necessary as the wedge blocks sometimes become loosened, and are apt to come into contact with the slide plates. Trouble also is occasionally experienced, owing to spikes, or other pieces of metal, bridging between the wedge blocks and slide plates.

330. Tie Plate Insulation: When tie plates are being installed in track where circuits are in use, unless the switch is cut out (Art. 227), the arrangements for insulating are made before the plates are placed in the track. On the other hand, if circuits are being installed on track where tie plates are already in service, they must be taken out and cut, Fig. 35, or otherwise insulated. It is desirable to substitute slide plates for the tie plates, while the insulation is being arranged.

When installing the lap joint shown in Fig. 37, holes must be bored in the tie to receive the bolt heads. A convenient tool for this purpose, is the expansion bit.

331. The types of insulation shown in Figs. 37-38, if assembled before being placed in the track, should be tested as explained in Art. 326, before being put into position. If it is desired to test these, or the type shown in Fig. 36, after they are put in place, the rail and switch point should be raised clear of the plate at one end, so that there is no metallic connection between them, after which the ammeter test is applied.

332. Pipe Line Insulation: The types of pipe line insulation illustrated in Figs. 39-41, are generally manufactured ready to be inserted into the pipe line. When being installed it is desirable to locate the insulation so that an existing pipe joint may be utilized, thus saving labor in cutting and threading.

As in the case of other insulations, a magneto or ammeter test should be made before the joint is attached to the pipe line.

333. Detector Bar Insulation: At switches and other points where detector bars* are used, it occasionally happens that an insulated rail joint occurs within the length of the bar. As the bar is attached to the rail on each side of the joint it is necessary that it be insulated in order that current will not be carried around the joint through it. One method of accomplishing this is shown in Fig. 156. It will be noted that the bar is offset

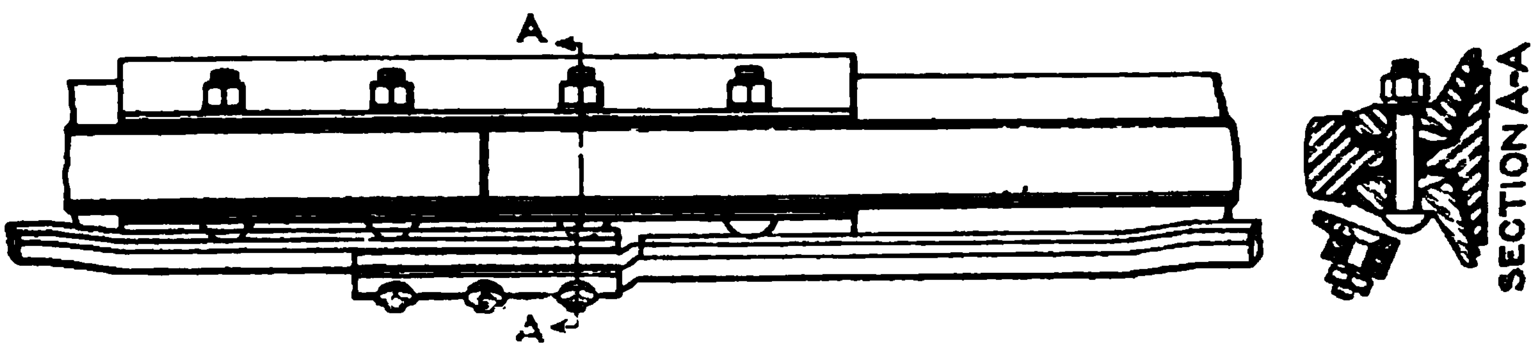


Fig. 156

so that it does not come into contact with any part of the insulated rail joint.

334. Methods of Insulating Cross-overs and Slips:** In Fig. 157 is illustrated a simple method of insulating a cross-over,

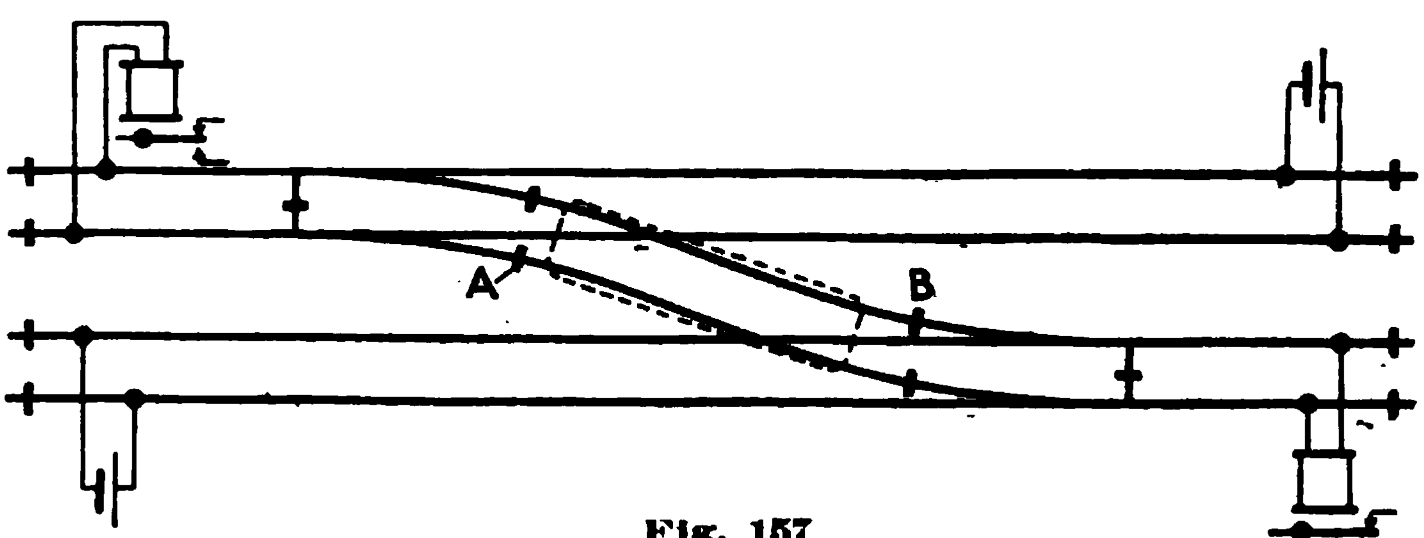


Fig. 157

connecting two tracks on each of which there is a track circuit. This arrangement is used where it is not required to have fouling protection as it is evident that a car can stand on the cross-over in the position shown dotted, without affecting either relay, the insulating joints A and B simply separate the two circuits.

*Described in **Mechanical Interlocking**.
**Other arrangements employed, applicable to various methods of signaling, are described in connection with the apparatus with which they are used.

In Fig. 158 is shown a more complete arrangement, two additional insulated joints being used and short fouling sections

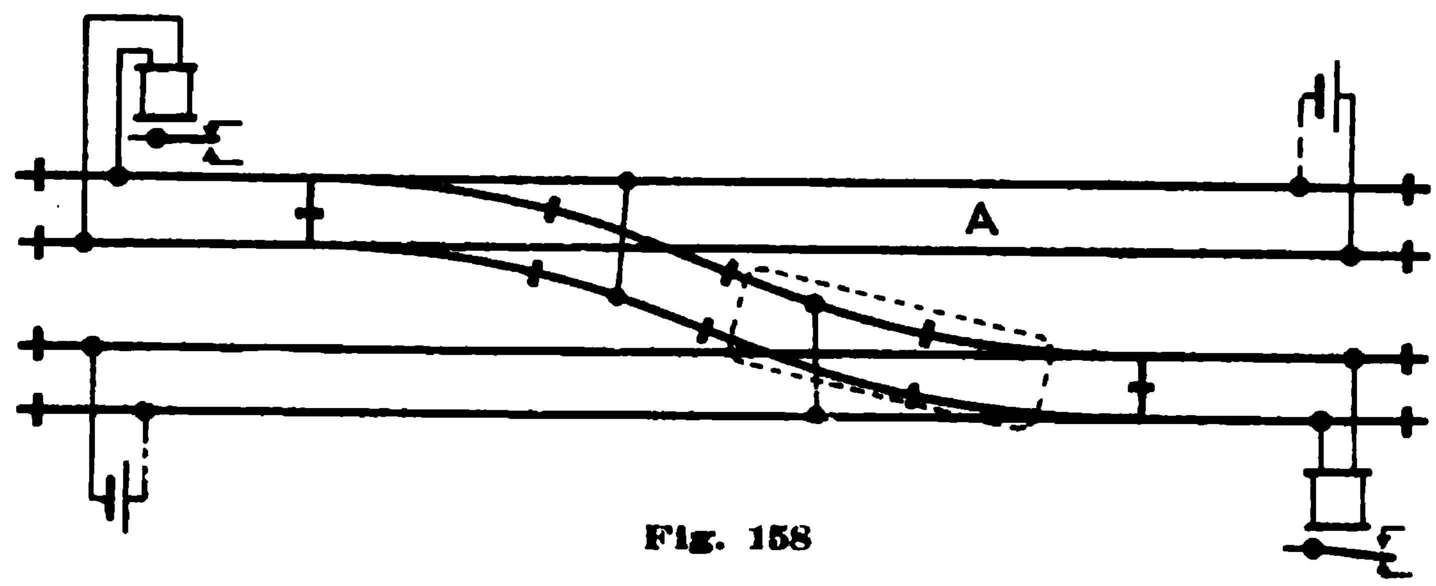


Fig. 158

thus provided, as described in connection with Fig. 127. It will be noted that a car cannot stand on any part of the cross-over without affecting either one or both of the relays. This arrangement is sometimes modified to correspond with those shown in Figs. 128-129. However, it should be understood that where cross-overs are installed in tracks of ordinary spacing, complete fouling protection cannot be procured, as it will be noted in Fig. 158, that if a car be in the position shown dotted, it will foul with track A, but will not affect its relay.

Fouling point. In cases where a siding runs parallel to a main track, the fouling point is usually taken where the siding begins to curve towards the main track, as shown in Figs. 127-129. At this point the tracks are generally 12 ft. center to center, although this distance is sometimes reduced to 11 ft. At crossings as in Figs. 130 and 159, or in instances where the siding approaches the main track at an angle, it may be necessary to locate the fouling point where the tracks are somewhat more than 12 ft. center to center, in order that the *overhang** of the cars will not cause them to foul.

335. A common method used for carrying a track circuit through a double slip crossing is shown in Fig. 159. As will

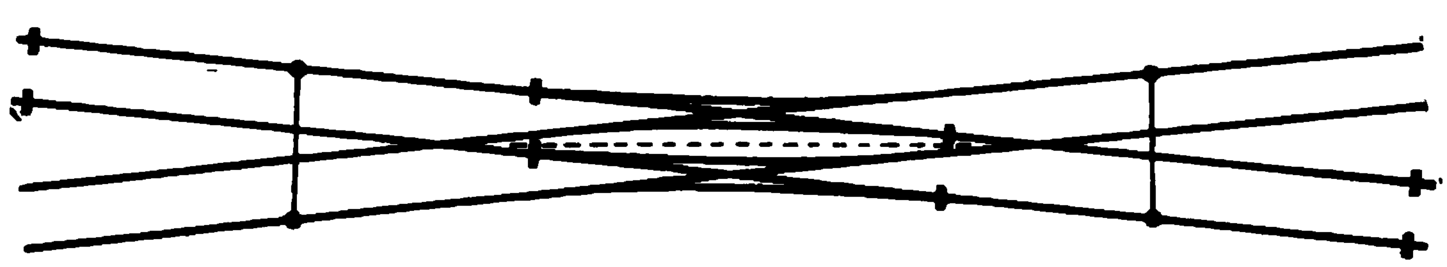


Fig. 159

*Overhang, as used here, signifies the distance from the end of the car to the first pair of wheels.

be seen, an insulated joint is installed at the toe of each end frog. The tie plates, switch rods, etc., are so insulated that there is no electrical connection between the opposite sides, in other words, the double slip crossing is electrically divided as indicated by the dotted line. It should be noted that the crossing and slip rails are *not* in series, and therefore although the presence of a train on any part of the track will be effective in operating the relay, a break in any of these rails will not be detected.

BATTERY SHELTERS

336. Particular care must always be exercised when locating apparatus near the track, that no part of it extends within the clearance line. While in many cases the distance from the track is governed by standard practice or by local conditions, where convenient it should be such that the maintainer will not be hindered in his work, by passing trains.

337. Battery Cupboards: These are frequently constructed as a part of the building in which the batteries are to be placed. However, when built separately (Fig. 46), they are generally set upon the floor, although in some cases they are raised above it, and when so arranged must be well supported.

338. Battery Boxes: Boxes of the types shown in Figs. 48-49, are usually set about half their depth into the ground.

When installing the type of box shown in Fig. 48, the hole through which the wires pass to the battery, may be bored at any convenient point.

As before noted the box shown in Fig. 50 is placed at a convenient height above the ground. When digging, a post-hole auger can frequently be used to advantage. The ground should be firmly tamped about the post when it is in place.

The battery box shown in Fig. 51 is generally set in the ground to the depth of the frost board, the ground being sloped, so that it will drain surface water away from the box.

339. Battery Chutes: When installing battery chutes, Figs. 52-54, their position in relation to the track is approximately as shown in Fig. 160. It will be noted that the trunking cap faces the track, this being generally desirable for convenience in running the trunking, although its position is quite frequently varied by the location of the relay boxes or other apparatus.

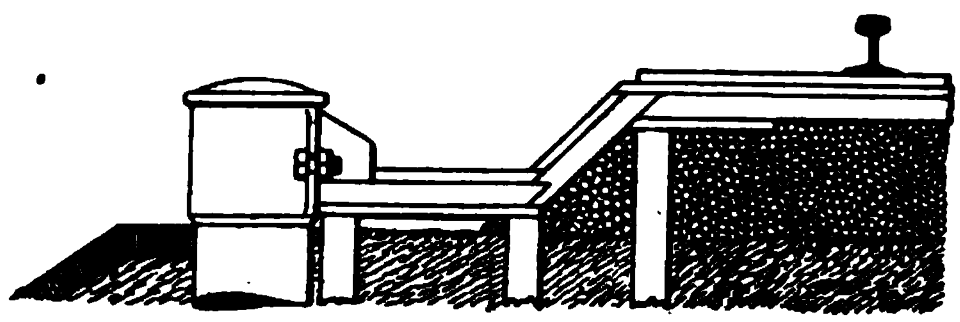


Fig. 160

340. When selecting a location for a battery chute, the following points should be considered with a view to securing the best results that circumstances will permit. First, wet ground should be avoided so as to prevent trouble in case a leak develops in the chute. Second, the drainage should be such that surface water will not collect around the chute, as if allowed to do so it is liable to flow into it. Third, there should be sufficient level ground about the chute to provide space in which to set the elevator, this being provided in some cases by filling, as shown in Fig. 176. Fourth, when trunking is to be run across the track from a battery chute, it is usually convenient to locate the chute directly opposite the space between the ties, through which the trunking is to pass. Fifth, it is not desirable to locate the chute in a bank sloping at a sharp angle as there may not be enough ground to keep the frost from the lower part of the chute. Where this is unavoidable the condition may be improved, increasing the depth of earth on the exposed side of the chute by filling. Sixth, difficulty in excavating will of course, sometimes become a governing factor.

341. When the location of a battery chute has been determined, the next step is to dig the hole to contain it. Where the character of the ground permits, a post-hole auger is by far the most expeditious method of excavating. In rocky ground the use of a digging bar, long handle round-pointed shovels (5 and 7 ft.) and a digging spoon, will be required.

If trouble is experienced on account of water flowing into the hole, it may easily be removed by the use of a bilge pump, of the type shown in Fig. 161.

342. To secure uniformity in the height of the chutes in relation to the track, a piece of board is laid across the rails in such a manner that it will extend over the hole, this being used as a gauge to measure its depth. This method is advantageous where the standard road bed has not been completed, in which case, the chute will be the proper height above the ground when the grading is finished. If however, the ground is at its permanent level, the top of the chute should be about 9 in. above the surface.

343. It is desirable to remove the cover (if detachable), frost board and elevator, before lowering the chute. A plank or the digging bar, should be placed in the hole, in such a manner as to form a guide for the chute in its descent. This will prevent the bottom of the chute from crumbling the earth from the side, into the bottom of the hole. The chute is now raised against the plank or bar and allowed to descend into the hole, care being exercised, in the case of an iron chute, that it is not broken by striking too sharply on any projecting rock.

The earth is now filled in and tamped, the chute being kept vertical in order that the battery jars may set properly.

344. Storage Battery Shelters: When it is desired to locate storage batteries in towers, or other buildings not specially designed to contain them, a satisfactory arrangement may be obtained by enclosing the rack shown in Fig. 58, in a suitable cupboard. Substantial floor support for the rack, should be provided, on account of the weight of the cells. It is desirable to locate the rack in front of a window, in order that the cells may be easily inspected, and to provide the necessary ventilation. If a window is not available the required ventilation can be secured by boring holes at the top and bottom of the cupboard through the walls to the outside of the building.

Instead of using a rack, properly constructed shelves may of course, be employed.

After the cupboard and rack or shelves have been erected, the acid-proof paint is applied (Art. 73).

345. A method for housing storage batteries is illustrated in Fig. 179. The arrangement shown is located at the foot of a signal bridge being used to feed a number of track circuits.

346. When installing the vault shown in Fig. 59, the hot pitch is applied to the walls with a brush, after the concrete has hardened. The brick floor is then laid in the following manner: First, a layer of sand ½ to 1 in. in depth is spread upon the concrete, and the brick laid upon it. The joints are then partially filled with sand upon which is poured hot pitch to the level of the top of the brick. Cans with suitable size spouts are used to advantage to pour the sand and pitch into the joints. When the pitch is setting sand is brushed over the floor mixing with the pitch and thus forming a clean footing.

347. *Maintenance.* Salts from gravity batteries deposit on the shelves upon which the cells are placed. In battery cupboards the salts accumulate quite rapidly, and should be frequently removed.

348. During exceptionally cold weather, at which time there is likelihood of gravity batteries freezing, it is sometimes necessary to keep them warm by placing lamps* in the lower part of battery cupboards or boxes. The same procedure is occasionally necessary with chutes and vaults.

Batteries in chutes are sometimes protected from low temperatures by the use of an additional frost board suspended about 1 ft. above the elevator. In some cases mineral wool is placed between the two frost boards. This material is also used to advantage when packed around the outside of the chute being kept in place by a wooden casing.

349. If water leaks or flows into a battery chute, it should be removed as soon as possible. This may be quickly accom-

*Hand or signal lanterns are convenient for this purpose.

lished with the aid of a small bilge pump, a type employed for this purpose being shown in Fig. 161.

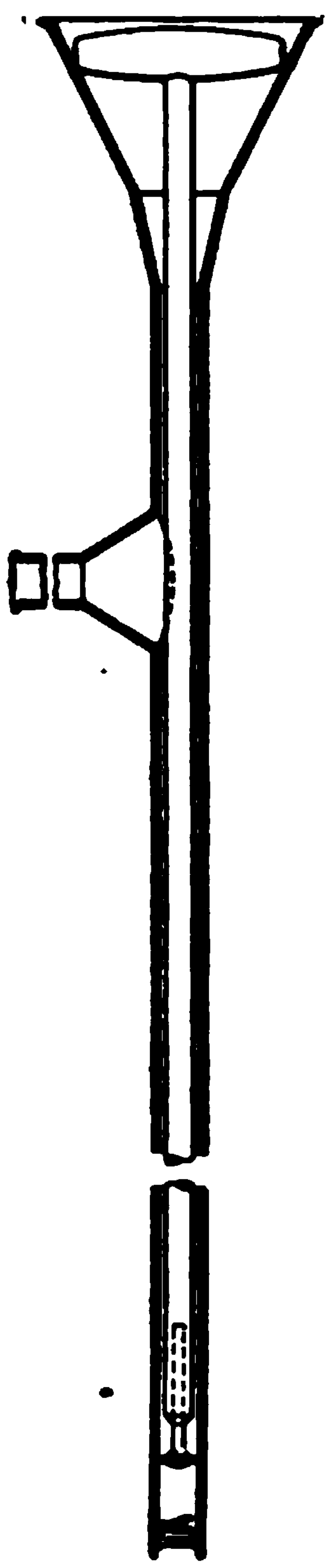


Fig. 161

The hinges on battery chutes are likely to become rusted by battery solution being spilled on them; on this account it is well to oil them occasionally.

RELAY SHELTERS

350. Relay Cases: It is desirable to locate relay cases, in such a manner, that the relays and other apparatus contained in them, may be convenient to inspect and work upon. They are therefore generally raised above the floor, being supported by brackets or other suitable means.

351. Relay Boxes: Relay boxes should be located at a convenient height above the ground (Fig. 75), and a good footing provided.

352. When setting the relay post, Fig. 76, in concrete, care should be taken to see that it is plumb, before the concrete sets. The box should not be fastened to the post, until after the concrete has hardened.

353. When making a concrete foundation for the type of post shown in sketch A, Fig. 77, a short piece of trunking is built into the top of the foundation in order to make a groove for the trunking through which the wires are carried to the bottom of the post.

In case wooden foundations are used the hole through which the wires pass, should of course, be bored before the base is bolted to the foundation.

354. Attaching relay boxes to signal posts although a satisfactory method in the case of iron posts set upon solid

foundations, is generally undesirable in the case of wooden posts, on account of the effect of vibration on the relays, due to the operation of the signal.

355. It is often convenient to attach relay boxes to retaining walls, in which case they are secured with anchor or expansion bolts. If the face of the wall is not plumb the box must be blocked out to a vertical position.

TRUNKING AND CONDUIT

356. It is generally considered desirable to provide trunking or conduit of such a size that *one-third* of its capacity will remain free for the installation of additional wires. Trouble has occasionally been experienced owing to mice gnawing the insulation off the wires in order to form a passage through the trunking. By allowing spare space, as noted, trouble from this source is lessened considerably.

357. Trunking: Trunking is placed either *below, at* or *above* the surface of the ground, according to the practice on different roads. When placed below it is located from 1 to 2 ft. beneath the surface, this depth being desirable to avoid interference from tools used in renewing and tamping ties. When the trunking is so located, stakes are not required to support it.

358. When trunking is placed at the surface, as is frequently the case in *cross-leads* passing under the rails, or when running parallel to the tracks between them, stakes are used to support the joints and ends, but not at other points. The top of the capping of cross-leads is usually from ½ to 1 in. below the base of the rail, the capping, where possible, being kept clear of the ballast, so that it can be removed without the ballast falling into the groove.

The height of trunking above the ground is determined to a considerable extent by local conditions, but in general, when running parallel to the track, the bottom is placed approximately

6 in. above the ground. When so arranged all joints are supported by stakes and in addition stakes are placed under the trunking, about 5 ft. apart.

359. It is considered good practice to place a *supporting strip* consisting of a piece of capping, between the stake and the bottom of the trunking. At joints the length of this strip varies from 12 to 24 in., but at other points a piece 8 in. long is usually sufficient. In the latter case, the supporting strip is often omitted with the smaller sizes of trunking.

360. *Drainage* is generally provided by boring $\frac{3}{8}$ or $\frac{1}{2}$ in. holes through the bottom of the trunking about 2 ft. apart.

361. When installing trunking at the surface or above ground, the lengths of trunking are first laid out and fitted, thus determining the location of the stakes which support the joints. The intermediate stakes are then located, being spaced as evenly as possible. The next step is to drive the stakes, which should be aligned, and set at the proper height. When the trunking runs parallel to the track, measurements may be made in the manner explained in Art. 342, a uniform distance from the track being assured by suitably marking the board used as a guage. At places where this method of measuring is not applicable, alignment may be secured by stretching a cord between the points where the stakes are to be set.

Stakes are usually driven with a *stake maul* and as before noted, should extend about 2 ft. into the ground.

Where supporting strips are used with stakes that do not support joints, the strip is first nailed to the top of the stake, after which the trunking is *toe-nailed** to the strip. This method of nailing is employed, because it is not desirable in any case, to drive the nails through the bottom of the groove, as they are apt to work up and chafe the insulation on the wires. In this connection care should always be taken that nails are not driven into the groove from the outside.

*Nails driven obliquely, see Fig. 166.

362. Capping is usually *nailed* in position with 6 or 8 d. wire nails, but in the larger sizes of trunking galvanized iron *gate hooks* are frequently employed in the manner shown in Fig. 162. These hooks are spaced about 4 ft. apart on each side.

Fig. 162

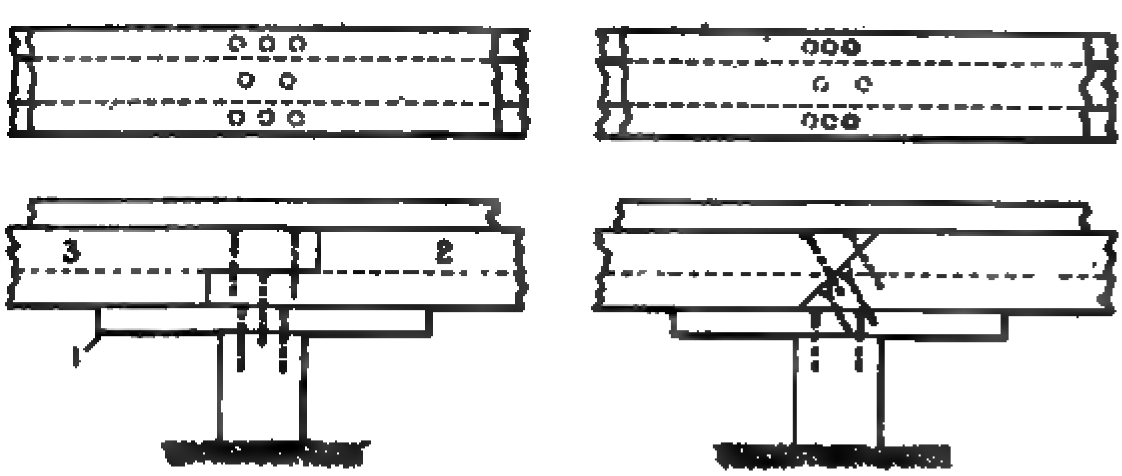
363. Where nails are used, the capping is held temporarily, until all the wires are put in place, by a few nails partly driven. When the capping is permanently secured in position the nails are *staggered*, being spaced about 2 ft. apart on each side. Ordinarily joints in capping should be made at least 1 ft. from the joints in the grooved lumber.

364. Joints in Trunking: In Figs. 163-169 are shown typical methods of constructing joints commonly required in running trunking.

Inside corners of trunking at turns should be *rounded* to prevent insulation on wires being injured.

A *try square* and *mitre box* are very convenient tools for use when fitting trunking.

365. Two types of joints used for splicing lengths of trunking, are shown in Fig. 163. When constructing these joints, the



A Fig. 163 B

supporting strip 1, is first nailed to the stake, after which the pieces of grooved lumber 2 and 3, are secured as shown. It is the usual practice to employ 8 and 10 d. nails at joints.

366. The *right angle joint* shown in Fig. 164 is built as follows: The supporting strip 1, is first nailed to the bottom of the trunking 2, and then secured to the stake, after which trunking 3 is fastened in position. It will be noted that capping 4 extends over trunking 3, thus aiding strip 1 in supporting the joint.

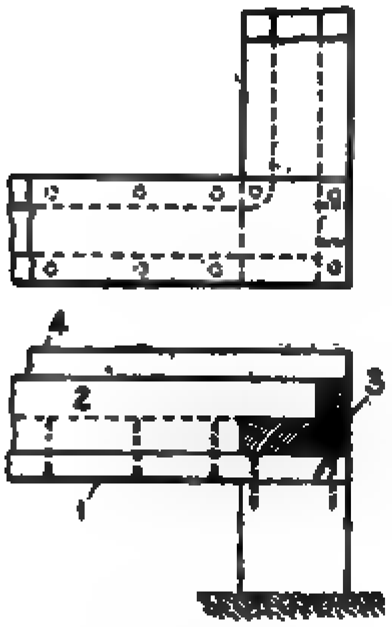


Fig. 164

Oblique angle joints in trunking are made in a manner similar to the right angle joint.

367. In making the *tee joint*, Fig. 165, the method of procedure is similar to that explained in connection with the right angle joint.

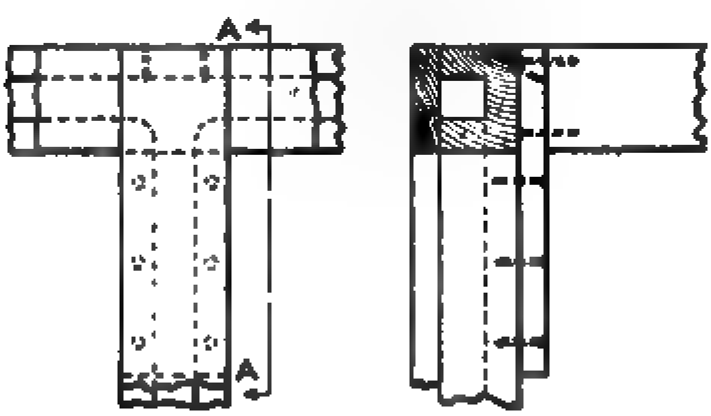


Fig. 165

368. In depressions and at other points it is often necessary to carry a run of trunking up the face of a retaining wall. In such instances the joints shown in Figs. 166-167, are used to advantage.

Joint A, Fig. 166, is used when a line of trunking approaches the wall at right angles and the joints in Fig. 167, when the trunking runs parallel to the wall. In the latter case, it will be noted that the vertical piece of trunking is turned so as to

bring the groove in front, permitting easy access to the wires. Owing to thus turning the vertical lead, the construction shown by sketch B is required where the width of the trunking is greater than the depth.

When constructing joint A, Fig. 166, the supporting strip is first nailed to trunking 1, and then to trunking 2, thus completing the joint before it is nailed to the stake. It is desirable to shape trunking 2 for joint B, before joint A is attached to the stake.

SECTION C-C

Fig. 166

369. Where the vertical trunking Fig. 166, is of considerable length, it should be secured to the face of the wall. A means of accomplishing this is shown in the illustration

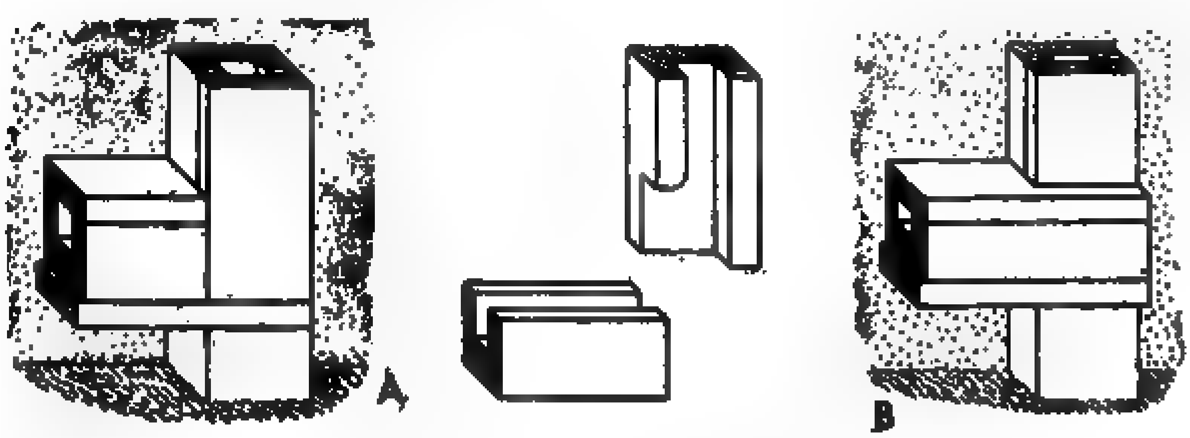


Fig. 167

in which a block of wood is nailed to the trunking and secured to the wall by $\frac{1}{2}$ in. expansion bolts. These supports are usually not required where the vertical trunking is less than 8 ft. long, being spaced 6 to 8 ft. apart where two or more are required.

A good method of procedure when installing these blocks is

as follows: After the stake at the foot of the trunking has been located, the holes for the expansion bolts are drilled, care being taken to insure that their position is correct. The blocks are then temporarily bolted in place, and the trunking set in its correct position and marked to indicate where the blocks are to be attached to it. The trunking is now removed and the blocks taken down and nailed to it, after which it is ready to be placed permanently in position.

370. The arrangement illustrated in Fig. 168, is frequently employed, especially when the trunking runs to the track from relay boxes or battery shelters, as shown in Fig. 160. After the stakes have been set, both joints should be cut and fitted, then joint A completed and secured to the stake by toe-nailing through the supporting strip. The next step is to fasten trunking 1 to the stake, after which trunking 2 is nailed to it

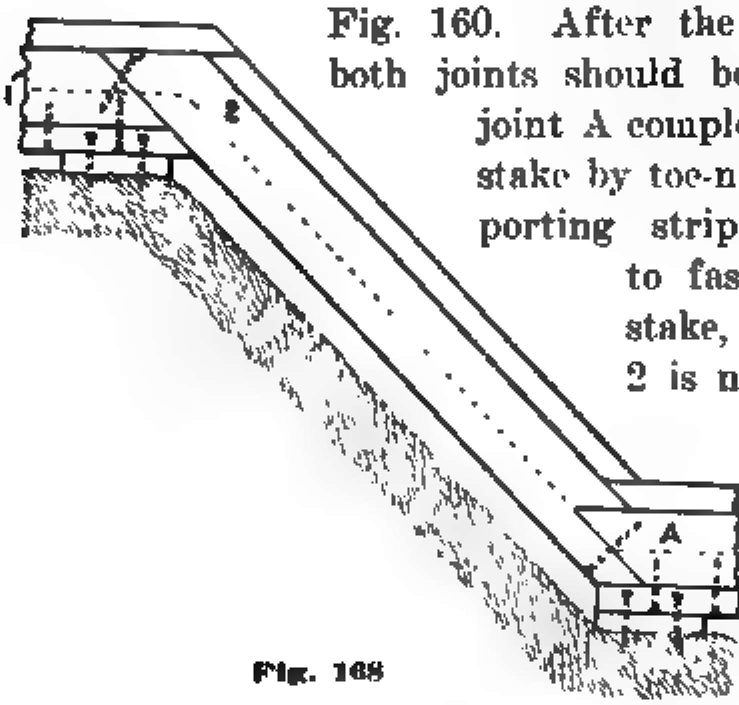


Fig. 168

371. When it is desired to make a *tee joint* similar to that illustrated in Fig. 165, with the exception that the trunking used in the *branch lead* is *smaller* than that in the main lead, the arrangement shown in Fig. 169, can be employed. The top of the grooved lumber of the branch lead is raised to that of the main lead by blocking A. As the capping of the branch lead is not, in this case, carried across the main lead as in Fig. 165, the necessary support is obtained by mortising the branch lead into the side of the main lead as shown.

Fig. 169

372. Slack Boxes: Instead of using the tee joints, shown in

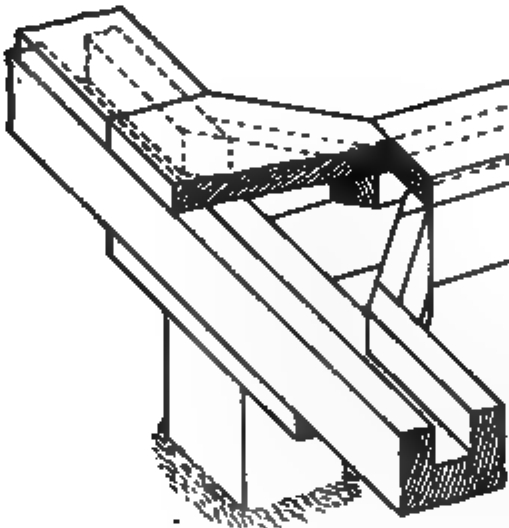


Fig. 170

Figs. 165 and 169, *slack boxes*,* a type of which is illustrated in Fig. 170, are often employed.

They allow a small amount of slack to be left in the wires and are convenient when tracing the circuits, as it is customary to tag the wires in these boxes.

On account of the difficulty of inspection, it is generally considered undesirable to have joints in the wires occur in the trunking, and with this in view, the slack boxes can be used to advantage for this purpose.

An application of the slack box is shown in Fig 176.

SECTION B-B

Fig. 171

373. Boot-legs: At points where the wires are brought out of the trunking to connect to the rail, a short piece of trunking known as a *boot-leg*, is generally used to protect them. Types of boot-legs are shown in Figs. 171-175 and their application in Fig. 176.

*Also called *junction boxes*.

374. Types of boot-legs used when the trunking is buried in the ground are illustrated in Figs. 171-173. The braces are made of pieces of capping one brace usually
hown in Fig. 172,

375. Various methods are employed to close the opening at the top of the *riser*, (vertical trunking). In
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376. The risers are located from ¾ to 2½ in. from the base of the rail, this distance being desirable to allow for slight changes in alignment of the track. The hole in the riser through which the wire extends to the rail, is generally high enough above the base of the rail, to allow the rail to be raised without forcing the boot-leg wire out of shape. In this connection, the top of the riser should be placed a

Fig. 173

minimum distance of 2 in. below the top of the rail, this distance being necessary in order that the riser will not be struck by the treads of worn wheels, in case the track settles.

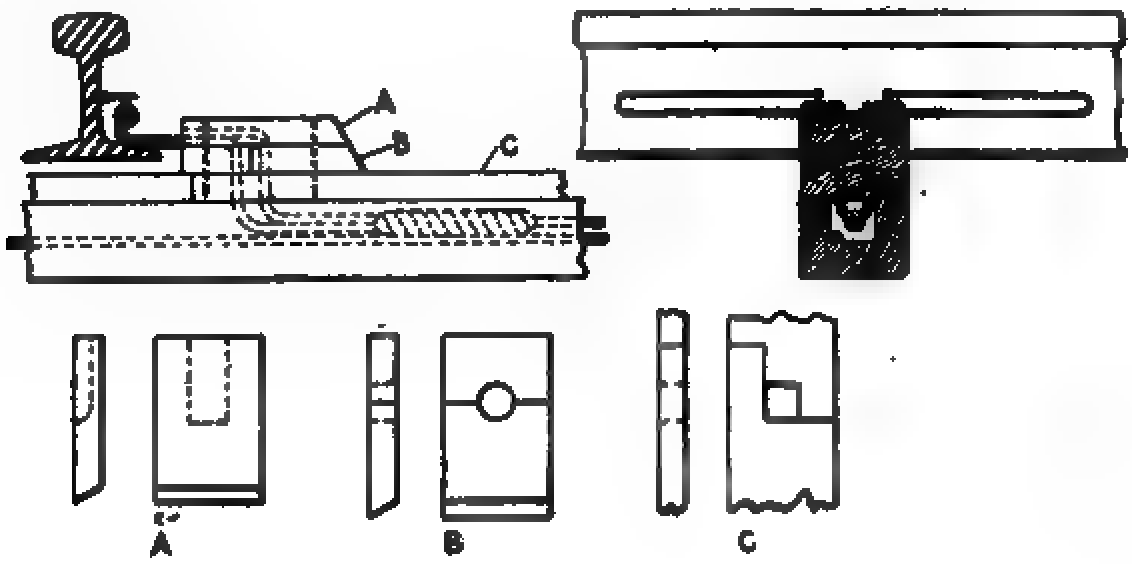


Fig. 174

377. The types of boot-legs shown in Figs. 174-175, are used where the trunking is run at the surface of the ballast. It will be noted that these are built upon the capping.

378. Trunking Layouts: In shown a typical trunking layout (carry the wires from the relay shelters to the rails. The cross-se two different methods of running the cross-leads. In the section where the trunking runs at the surface of the ballast, the boot-legs will of course, be of the type shown in Figs. 174 or 175, whereas with the arrangement shown in the lower section, the types illustrated in Figs. 171-173 are employed. While it is desirable, as mentioned in connection with Fig. 85, to attach the boot-leg wires as close

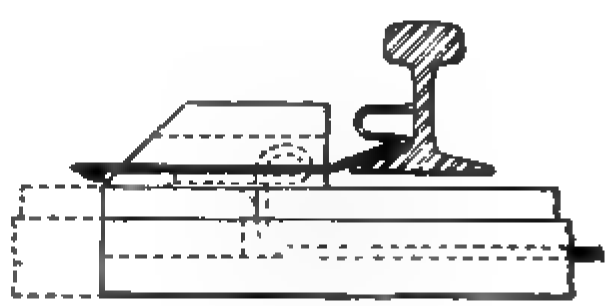


Fig. 175

to the insulated joints as possible, nevertheless as indicated

in Fig. 176, the boot-leg is placed far enough from the end of the joint to permit convenient tamping of the joint ties without injuring the trunking. Another consideration is

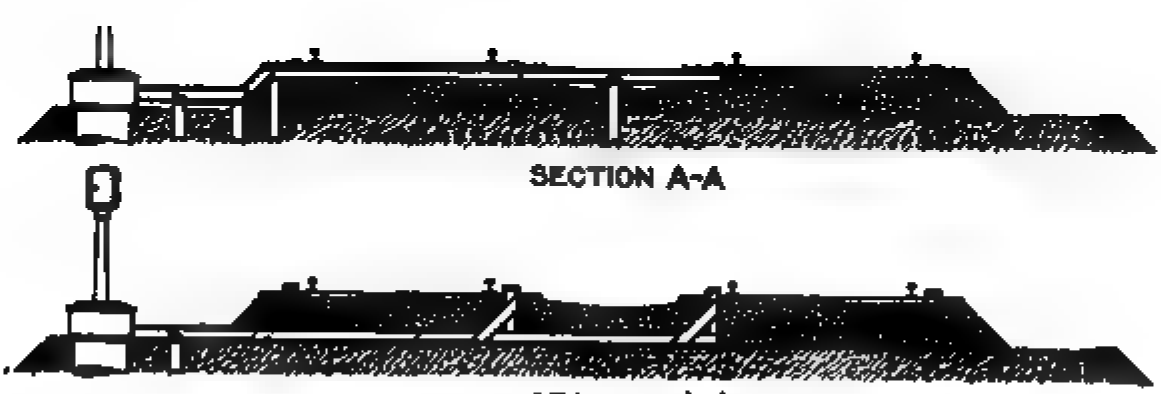


Fig. 176

the necessity for preventing the boot-leg wires from coming into contact with any part of the insulated joint and thus bridging part of the insulation.

379. Trunking Leads at Towers: If track batteries or relays are located in a tower, the wires may be carried into the building in the manner shown in Fig. 177. It will be noted that a riser leads up the side of the tower to a hole bored in the wall, through which the wires pass. It is desirable to have the trunking inside the building, at least 4 in. above the floor in order to keep it free from water and dirt, when the floor is being cleaned. Accordingly the hole through the side of the building should be bored at the proper height to secure this clearance.

Fig. 177

380. When installing trunking in a wooden tower it is generally secured in position by toe-nailing. If it is desired to attach it to a brick or concrete wall the method shown in Fig. 166, can be employed to advantage. The capping is usually held in place by round head wood screws. When making joints in buildings, it is customary to omit the supporting strip, the wall affording the required support.

381. Conduit: A typical installation of fibre conduit is illustrated in Fig. 178.* It is usually buried to a depth of about 2 ft., and the boot-legs are protected by small concrete piers as shown. In some instances the entire conduit is laid in concrete.

382. *Maintenance.* As trunking installed underground is subject to alternate wet and dry conditions and also to the

*Also see Fig 59.

attack of worms, it will in some cases rot very quickly, unless treated with some wood preservative. When allowed to rot

Fig. 178

considerably it not only fails to protect the wires, but tends to collect and hold moisture about them.

On account of heaving by frost in the ground, trunking leads located above the surface sometimes become displaced and should therefore occasionally be aligned.

PAINTING

383. It is customary to paint all iron and wood work exposed to the weather.

Paint should not be applied in wet weather, nor to any surfaces until they are clean and dry, or until the previous coating has thoroughly dried.

Surfaces covered with rust, grease, dirt or other foreign substances, should be thoroughly cleaned by scraping or other suitable method, before paint or oil is applied.

384. Iron Work: It is the general practice to apply to iron work, a priming coat of *red lead paint* and two finishing coats of the desired color, in many cases *black asphaltum* or *graphite paint* being used for this purpose.

Red lead paint should be prepared as follows: A suitable quantity of red lead is permitted, for 24 hrs. ,to absorb its full capacity

of raw linseed oil, after which it is stirred to the consistency of a stiff paste. As red lead paint thickens rapidly, only as much of this paste as it is intended to apply in the following 6 hrs., is thinned with the necessary amount of linseed oil and drier.

Iron work should be repainted at intervals frequent enough to prevent rusting. If however, rusty spots appear they should be touched up with red lead paint before the finishing coat is applied.

385. Wood Work: The general method employed when painting exposed wood work used in track circuit installations is similar to that described in connection with *Signal Towers.* In many instances, metallic oxide paints are used for this purpose.

Trunking placed above or at the surface of the ground should of course, be painted, but it is not the practice to paint that which is buried. As the trunking is usually painted after the capping has been nailed in position, the covered portions of the trunking are of course, not painted.

As exposed trunking generally receives considerable wear, it should frequently be re-painted to keep it in good condition.

If the painting of wood work has been neglected until the wood has become very dry and porous, a coating of pure linseed oil should first be applied to fill the pores and prevent checking.

RELAYS, LIGHTNING ARRESTERS, AND TERMINAL BOARDS

386. Relays: The general instructions for the installation, maintenance and testing of these instruments, given in the section on *Relays,* should of course, be followed in track circuit work.

387. Typical relay installations are shown in Figs. 75. 76, 78 and 179. In the latter illustration the relay cupboard is built into the leg of a signal bridge. The solid wires are brought

up from conduit and as shown are carried through the wooden partition to the relays. The space behind this partition, which is occupied by the wires, is enclosed by a false back which opens, affording easy access to the wiring.

Fig. 179

388. When placing the relay in the shelter, it should be so located that the operation of the contacts may be readily observed.

389. *Maintenance.* It is very important that relays be frequently inspected. Sometimes lightning discharges injure the contact points by arcing, materially increasing their resistance, and in extreme cases fusing them together.* If a relay is found with its contacts injured in this manner, it should be

*See **Relays.**

replaced. Trouble in other parts of the relay is also apt to occur, especially in case of heavy discharges.

390. Where track circuits are carried through contacts on relays, it is desirable to occasionally test the conductivity of these contacts, as even a small amount of resistance between them will cause a drop in voltage which will be likely to interfere with the operation of the circuit. Back contacts which act as shunts at cut sections (Art. 169), should also be tested.

In some types of polarized relays, the glaze which forms on the surfaces of the polarized contacts, inserts considerable resistance in the circuit. This is especially noticeable in relayed polarized track circuits in which the polarized contacts which act as a pole changer must occasionally be cleaned to insure proper operation. This may be accomplished by drawing a piece of fine emery cloth between the contact surfaces.

It is occasionally necessary to clean relay contacts which are not enclosed.

391. Lightning Arresters: In cases where lightning arresters are used in connection with track circuits they are usually fastened with screws to the sides or back of the relay box, in a manner similar to that shown in Fig. 76. In towers the arresters are frequently grouped, being mounted in a suitable case at a convenient point on the wall, although in some instances they are located in the relay case.

392. As porcelain is quite brittle, care must be exercised when mounting arresters made of this material, rubber washers being provided with some types to be placed between them and the wood upon which they are mounted.

393. When a number of arresters are mounted side by side, the ground posts are frequently connected together by brass links, thus avoiding the necessity for carrying the ground wire to each arrester.

394. *Grounds.* Unless a good damp ground is used in connection with lightning arresters they cannot be expected to

produce satisfactory results. The wire from the arrester to the ground connection should be run as direct as possible, avoiding any great length of wire which would insert resistance, and also avoiding turns and sharp bends which tend to retard the discharges.

The ground clamp shown in Fig. 69, should not be attached to gas, steam, or hot water pipes, on account of the unreliability of the ground generally secured through them. Before attaching the clamp, the pipe should be thoroughly cleaned, all rust or corrosion being removed, thus producing a bright surface.

In some instances the clamp is not used, the wire being soldered to the pipe. The pipe is first cleaned as noted, then tinned and the wire given about six turns around it, spaced a slight distance apart, after which the joint is thoroughly soldered. It is very difficult to solder on to a pipe containing water and therefore the water should if possible, be drawn off.

When soldering the wire to the terminal, it should be removed from the clamp and the inside tinned. The end of the wire is then tinned and *sweated* into the terminal. In some cases the terminal is omitted, the wire being secured under the check nut.

Grounds are sometimes secured by bonding the ground wire into an iron battery chute.

395. When installing the ground plate shown in Fig. 70 the procedure is as follows: First the hole is dug to a depth sufficient to reach permanently damp earth, usually not less than 6 ft. The next step is to cover the bottom of the hole with the coke or charcoal, to a depth of from 1 to 2 ft., which should be thoroughly wet down and tamped. The plate is now laid upon this bed and covered with an equal amount of coke or charcoal, which is wet and tamped as before, after which the hole is filled, water being used to settle the earth.

As there is no check on the resistance of grounds, they should be tested* when installed and occasionally thereafter.

396. *Maintenance.* In most types of spark gap arresters, there is a possibility of the gap becoming bridged by conducting material and thus permanently grounding the circuit. Where the gap is between metal parts the arc sometimes tends to fuse

*See **Magnetism and Electricity.**

them together, while in carbon arresters the lightning discharges tends to loosen particles of carbon which in time collect and bridge the gap. As the grounding of the circuits is apt to cause serious trouble, arresters should frequently be inspected and if necessary tested with a magneto.

When inspecting wooden base arresters, it should be observed whether the spark gap has been bridged by carbon (Art. 76), which if present, should be removed; however, if badly carbonized the arrester should be replaced.

In choke coil arresters so placed that a good view of the gap cannot readily be obtained, a piece of paper may be passed between the coil and the ground plate, to insure that there is no connection between them.

397. Terminal Boards: When mounting the terminals shown in sketch A, Fig. 72, they should be spaced about 1 in. apart, center to center, and properly aligned to produce a neat appearance. If there are more terminals to be installed, than the width available permits to be placed in the manner shown, they may be placed in two rows and staggered, as in Fig. 73, being spaced slightly farther apart.

WIRING

398. As failures resulting from defective wiring are frequently very difficult to locate and sometimes of a dangerous nature, the installation of this part of the work should receive very careful attention.

399. Wire: As good insulation between the wires is essential, and as moisture must be guarded against, all wires placed in trunking outside of buildings is *rubber covered.*

400. *Relay and Battery Leads.* Batteries and relays are connected to the rails with rubber covered, soft drawn, solid copper wire. The sizes of wire used for this purpose varies considerably, No. 6 to No. 10 B. & S. G. being employed.

401. It is the general practice to use rubber covered *stranded wire* to lead from the trunking into battery chutes to the elevators, No. 12 B. & S. G. being commonly used for this purpose. The elevators are generally wired with No. 12 or 14 B. & S. G. *solid wire.*

As before noted *flexible wire* is also used between relays and terminal boards or lightning arresters, the ordinary size employed being No. 14 B. & S. G. Single conductor lamp cord of the same size is also frequently used for this purpose.

402. Office wire is sometimes used inside of towers, being connected to the rubber covered wire at the point where it enters the building.

Between lightning arresters and their ground connections, it is not considered desirable to use a smaller wire than a No. 6 B. & S. G., or its equivalent.* Bare or rubber covered wire is used for this purpose (above ground) although the latter is generally preferred as its insulation affords better protection against accidental grounding.

403. *Boot-leg Wires.* It is not the custom to attach the rubber covered wire which is run in the trunking, directly to the rails, although this is done in some cases. As shown in Figs. 171-175 a separate piece of wire, known as a *boot-leg wire,* is bonded into the rail and to this is soldered the rubber covered wire. The boot-leg wires are made of soft drawn bare copper wire, or of galvanized iron wire, the same size as that used in the rail bonds. As considerable trouble may be caused by a defective boot-leg wire, some engineers favor the use of copper wire on account of its durability. However, iron wire being stronger, is often used for boot-leg wires where it is especially necessary to guard against mechanical injury.

404. *Jumpers.* Jumpers for fouling sections (Figs. 127-129), crossing frogs and transpositions (Fig. 209), are generally placed in trunking, rubber covered wire of the same sizes as that used for battery and relay connections, being employed. In some instances these jumpers are made of bare copper or galvanized iron wire the same size as rail bonds.

*It is considered good practice to use two No. 8 B. & S. G. wires, in place of a single wire.

INSTALLATION

405. When laying wire in the trunking, it must not be kinked or its covering injured. In the former case, the wire may be broken without being at once discovered, and in the latter, the injury to the covering may admit moisture and possibly cause a short circuit, or leakage of current.

When installing wires in conduit, they are usually fished into place, the *fish wire* either being put in position when the conduit is installed, or drawn into place with a *snake.* When wires are being drawn through conduit or iron relay posts, etc., the necessary precautions should be taken to guard against injury to the insulation.

406. The wires should be laid loosely in the trunking and all possible slack allowed at turns.

The use of the pitch compound mentioned in Art. 104 is considered especially desirable in underground construction. When this compound is used, it is first applied hot to the inside of the trunking and allowed to cool; the wires are then laid in the trunking and covered with the melted compound, care being taken that it is not hot enough to burn the rubber or braid. The inside of the trunking should be perfectly dry when the operation is commenced and no moisture should be allowed to get into it while the work is in progress.

As it is not easy to change the wires after they are "pitched in", it is well to test them with a magneto to insure that they are properly arranged, before applying the pitch.

407. Joints: The general directions given in *Line Construction* for making joints in rubber covered wire, apply in track circuit work.

As few joints as possible should be made in the wiring, it being better policy to waste a small amount of wire than to have joints. However, when joints are unavoidable, they should not be placed in trunking except in special instances as noted hereafter, but should be made in slack boxes, where they may be easily located and inspected.

408. Boot-leg Wires: In Figs. 171-175 are shown various types of boot-leg wires. It will be observed that the wires are formed so as to allow for considerable creeping of the rail without subjecting them to any severe strain.

Where the rubber covered wire is smaller than the bare wire, trouble has been experienced by the small wire being broken at point A, Fig. 180, on account of vibration caused by passing trains. On this account, the boot-leg connections are generally so arranged that this part of the wire is subject to as little vibration as possible. The bare wire is attached to the rail in the same manner as the rail bonds.

Fig. 180

It is generally considered desirable to allow a small amount of slack in the rubber covered wire as shown in Fig. 171, this being advantageous if it becomes necessary to make a new joint.

409. When installing the boot-leg connection shown in Fig. 171, a sufficient length of rubber covered wire is allowed to provide the slack and make the joint. This wire is then passed through the hole in the top of the riser, after which the end of the wire is prepared for making the joint. After the bare wire has been cleaned at the point where the joint is to be made, the rubber covered wire is formed around it and the joint soldered and painted with P. & B. compound. The next step is to shape the bare wire and bond it into the rail. The loop in the rubber covered wire is then formed and the slack drawn back into the riser.

The turns of rubber covered wire to the left of the soldered joint assist in preventing injury to the joint from vibration.

410. When making the boot-leg connection shown in Fig. 172, the bare wire is doubled and passed through the $\frac{1}{4}$ in. holes in the riser (sketch C) after which it is bent into shape and bonded into the rail. The rubber covered wire is now passed through the $\frac{1}{2}$ in. hole in the riser and soldered to the bare wire.

The joint is given the necessary protection against vibration by the attachment of the bare wire to the riser.

411. The method of procedure for making the joint used in the boot-leg connection, Fig. 173, is illustrated in Fig. 181. Two pieces of bare wire are twisted together as shown at A. The rubber covered wire is then twisted upon it, first as shown at B and then looped and returned as shown at C. After soldering as shown at D, the joint is coated with P. & B. compound, wrapped with one layer of friction tape, again coated with P. & B. compound, again wrapped with tape, and finally coated with the compound, appearing when completed, as shown at E.

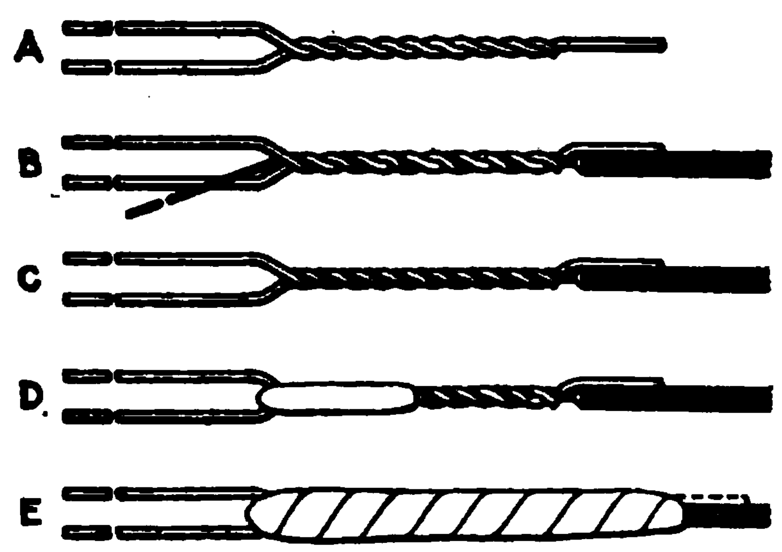


Fig. 181

The taping of the single bare wire to the insulated portion of the rubber covered wire, gives the joint the necessary protection against vibration. The single bare wire is sometimes extended beyond the taping and arranged as shown dotted in Fig. 173, thus assisting in overcoming vibration.

412. It will be noted in Figs. 173 and 175, that the bare wires extend from the trunking along the rail *against traffic.* As the rail generally creeps *with traffic,* this arrangement provides against trouble from that source.

413. In the boot-leg connection illustrated in Fig. 174, which as before noted, is designed for use with trunking at the surface of the ground, the arrangement of the wiring is similar to that shown in Fig. 171, with the exception that an additional piece of rubber covered wire is attached to the bare wire, this being jointed to the main lead of rubber covered wire just inside the trunking.

By referring to detail sketches A, B and C, Fig. 174, it will be observed that the capping and blocks are cut in such a manner, that by taking up the capping C the entire wiring will be free for inspection or repairs.

414. The boot-leg shown in Fig. 175 is built by attaching a

piece of grooved lumber, inverted, to the capping. It will be noted that the capping is cut at the point where the wire passes through it as in sketch B, Fig. 174.

415. Where the bare wire is attached to the rail with bonding plugs, it is usually made from a bond wire.

Boot-leg wires on account of the position which they occupy, are subject to considerable hard usage, and therefore frequent inspection is necessary.

If the rail is found to be creeping, it should not be allowed to bring a strain upon the wiring, the slack in the rubber covered wire being paid out to meet the altered condition, and when necessary the bare wire being cut close to the channel pins, cleaned and re-bonded into the rail at the proper point.

When rails are being renewed boot-leg wires should be cut off close to the rail and stapled to the ties as far away from the rails as possible, in order to keep them in good shape for bonding into the new rails.

If a soldered joint between the rubber covered and bare wire is to be made after the latter has been attached to the rail, which is often necessary when making repairs, the use of a *gasoline torch* will be found convenient.

416. *Jumpers.* When jumpers are made of rubber covered wire they are placed in trunking and installed with the regular boot-leg wire. When made of bare copper or iron wire they are bonded directly into the rail, and as before noted are frequently twisted together and stapled to the ties. The latter arrangement although more subject to mechanical injury is easily installed and can be readily inspected.

417. Single Rail Circuits: When installing the wiring for single rail normally closed track circuits, all relays should be connected to the track with separate leads.

If the wiring should be arranged as shown in sketch A, Fig. 182, a break or poor connection in the common lead X, may cause relay Y to be falsely energized by battery Z, the current taking the path indicated by the arrows. If the position of

battery Z and relay Z should be reversed bringing the two relays together, a break or poor connection in the common wire X,

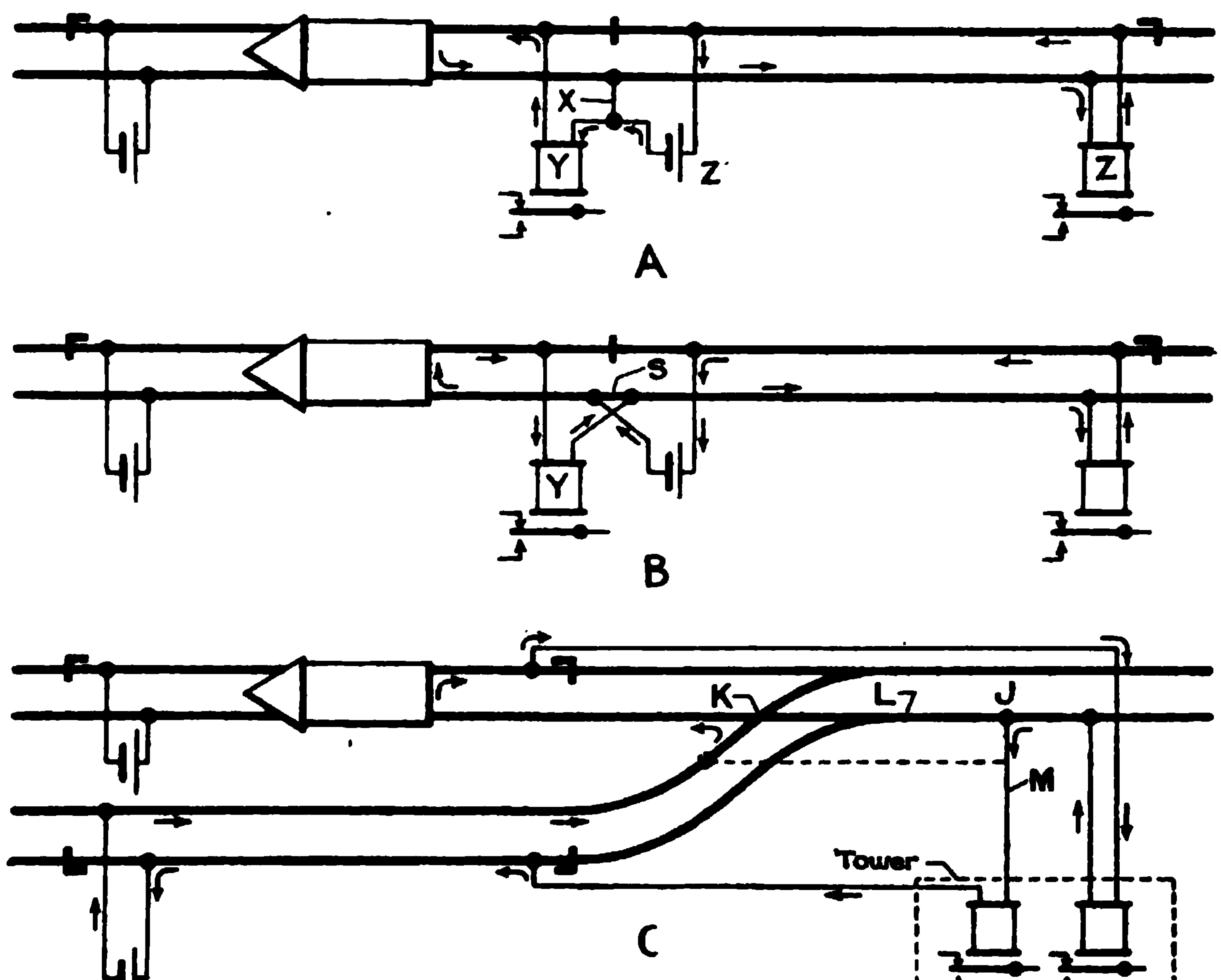


Fig. 182

would also place the two relays in series, producing an effect similar to that described.

Care should be taken that the leads are not crossed as shown in sketch B, as in case of a broken rail at point S, relay Y will be improperly energized, current passing through the path indicated by the arrows.

In all cases relays and batteries should be so connected to the track that a relay will not be placed in series with a battery or relay of another circuit by a broken rail or poor bonding. Such a condition is illustrated in sketch C, in which the relays of two single rail circuits, while connected to the track with separate leads, use one rail as a common conductor from point J to frog K and therefore in case of a break or poor bonding in this rail, for instance at point L, the relays are placed in series and with a train on either of the circuits the relay for that circuit may be falsely energized as indicated. To overcome this one of the leads, for example M, should be connected as

shown dotted so as to avoid having rail J-K act as a common conductor for both circuits.

418. Wiring in Battery Shelters: As before noted it is the general practice to use flexible wire to lead from the trunking into the battery chutes. This is desirable as the care of the batteries require that the elevator be often removed from the chute and consequently if solid wires were used, the frequent bending would tend to break them and in any case the elevator would be more difficult to handle.

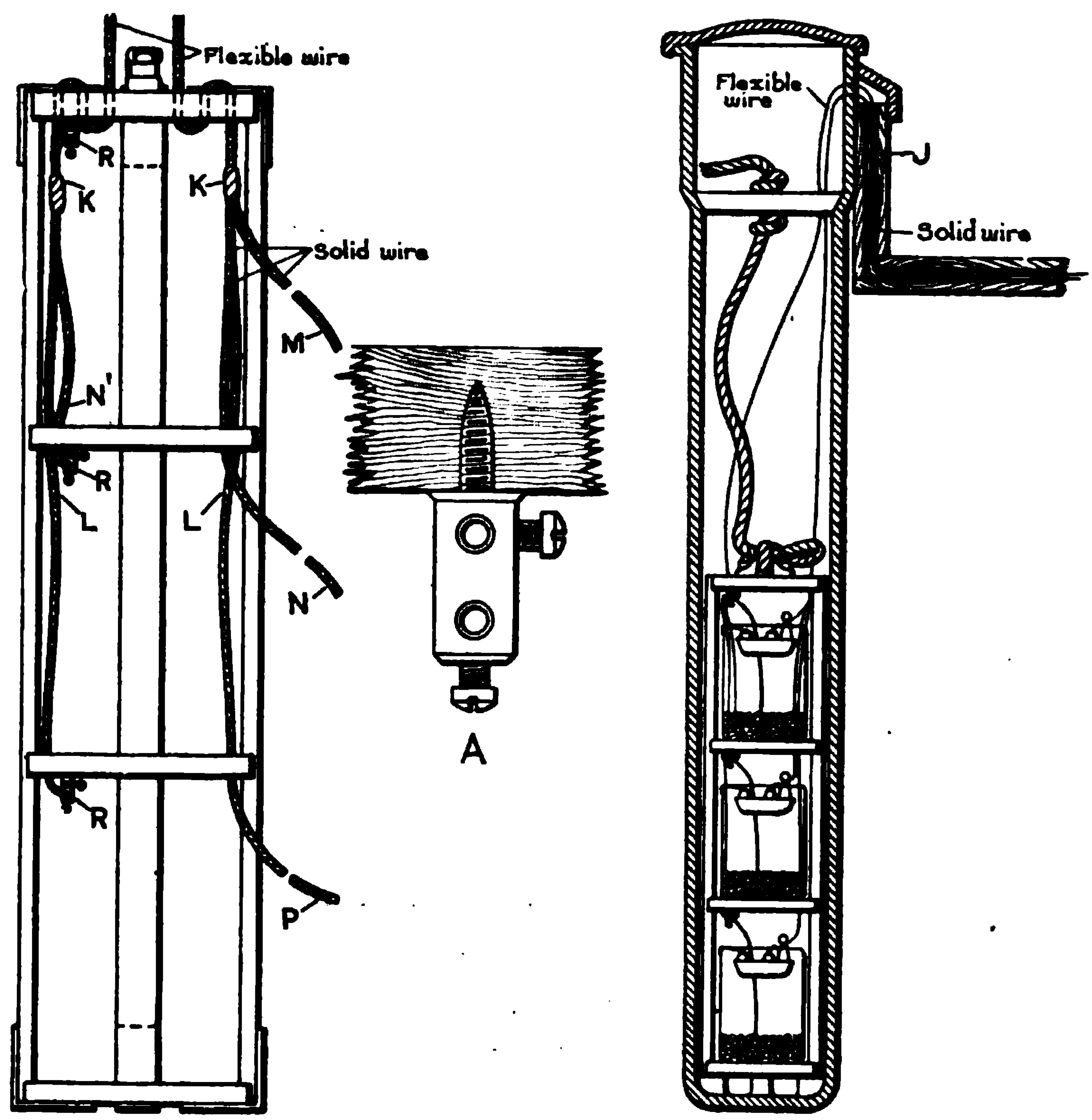


Fig. 183

419. The *wiring of a chute* for a gravity battery is illustrated in Fig. 183, together with an enlarged view of the elevator wiring.

It will be noted that the flexible wire is joined to the solid

wire in the riser and to solid wiring in the elevator, directly beneath the upper head.

The flexible wire is often carried straight through the upper head, instead of in the manner illustrated, although when arranged as shown considerable support is given to the wires and the possibility of their twisting and therefore bringing the battery connectors into contact with the sides of the chutes and thus grounding the circuit, is avoided. In order to secure the best results the wire should fit the holes snugly. When carried straight through knots are, in many cases, tied in the wire on each side of the upper head to provide the necessary support.

When two cells are to be placed in a three-cell elevator they are usually set on the lower shelves, thus securing the benefit of the full depth of the chute.

A suitable notch is cut in the side of the frost board through which the wires are carried.

420. Two types of straight joints used when connecting flexible to solid wires are illustrated in Fig. 184. Either of these are applicable for joining the flexible to the solid wire in the trunking at point J, and also in the elevator wiring if required. The *wrapped joint* shown at A is made in the same manner as the similar joint shown in *Line Construction.*

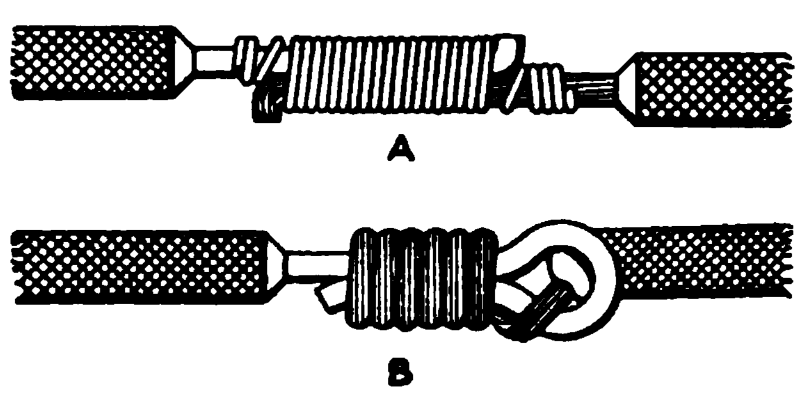


Fig. 184

421. Two types of *branch joints* required in elevator wiring are illustrated in Fig. 185. It will be observed that these are developments of the *loop joint* shown in sketch B, Fig. 184. The joint shown at C is used at points K, Fig. 183, and that shown at D, at the same point when only two cells are installed.

Instead of running two wires from K to L, branches N and N′ are sometimes connected at points L. Branches M, N, and P which are usually

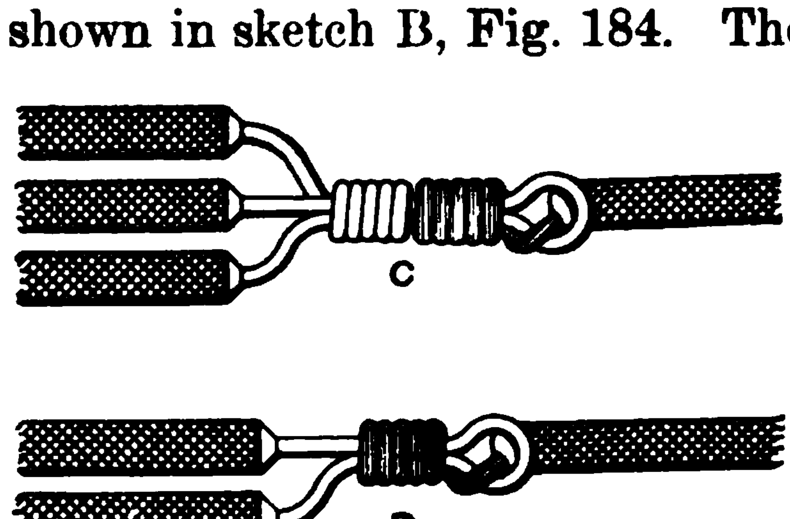


Fig. 185

made about 14 in. long are wound into a spiral and connected to the *battery zincs.* The slack wire which is taken up in the spiral, is required when the end of the wire becomes worn out by the binding screw, and in consequence must be cut off. It also provides a flexible connection.

When removing the insulation and cleaning flexible wire preparatory to making a joint, it is necessary to exercise considerable care to avoid cutting the strands. The strands of flexible wire are twisted together and as they become untwisted when being cleaned, should again be twisted tightly together, before making the joint.

All joints are, of course, soldered, painted and taped as described in *Line Construction.*

422. The binding posts R, Fig. 183, an enlarged detail of which is shown in sketch A, illustrate one method of arranging the connections to the *battery coppers.* The use of the binding post prevents the copper terminal from getting into contact with the side of the chute.

When connecting to this type of post, solid wires after being cleaned, are doubled before being inserted into the hole.

Fig. 186 illustrates another method of connecting to the battery copper. In this case, the terminal is not attached to the elevator but is soldered to the branch from the elevator wiring, which is formed into a spiral to provide flexibility. Before making the joint the terminal is tinned where the connection is to be made. It is not customary to tape this joint although it may be painted with P. & B. compound.

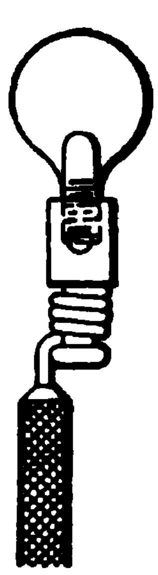


Fig. 186

423. In Fig. 187 is shown another type of battery connector used under the same conditions as that shown in Fig. 186. The branch from the elevator wiring is soldered into the groove which is first tinned, and the wire from the battery copper is secured in the hole by the thumb screw.

Fig. 187

424. With some methods of wiring battery elevators, there is a possibility when removing the cells for renewal, etc., of

getting the branch wires mixed and connecting them to the wrong elements of the battery, thus reversing the polarity and causing trouble, especially in polarized circuits. To avoid this possibility of trouble the connections to the battery copper should be arranged, either as shown in Figs. 183, 186 or 187, or by other suitable means, so that they can be readily distinguished from the zinc connections.

425. It is the practice in some cases, instead of using a *single* No. 12 B. & S. G. flexible wire for each lead, to employ a *twisted pair* of No. 14 B. & S. G. for each conductor, so that in case one wire of a pair should break, the other will still be effective in maintaining the circuit. A type of joint connecting one solid to two flexible wires suitable for use in such installations is shown in Fig. 188.

Fig. 188

426. The *wiring of battery boxes* is usually very simple, the solid wire from the trunking being brought directly into the box. In the wooden boxes the wires are sometimes fastened to the sides with cleats.* A branch wire should be provided for attachment to each zinc, as indicated in Fig. 190, which represents a typical arrangement for wiring three cells in multiple, and battery connectors, types of which are shown in Fig. 189, provided for making connection to the battery coppers. The branch wire is soldered into the groove in the thumb screw connector. The connection at point A can be made satisfactorily in the manner illustrated in Figs. 186-187.

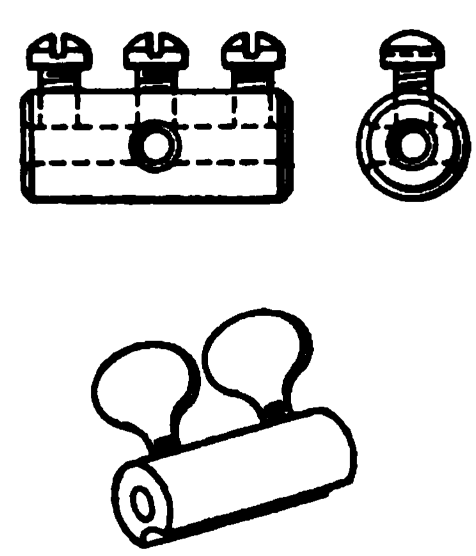


Fig. 189

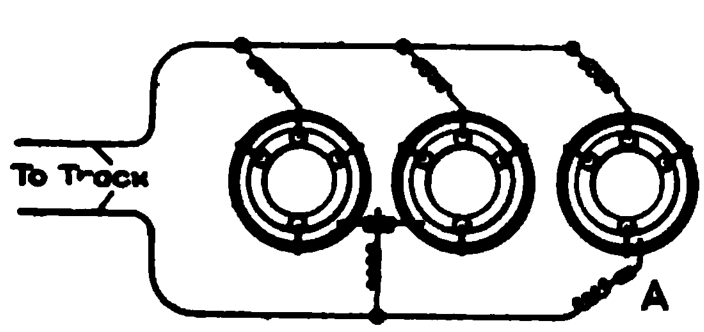


Fig. 190

427. When *wiring battery vaults and cupboards,* cleats are often used to advantage. Staples are usually considered un-

*See Art. 433.

desirable as they are apt to injure the insulation, although when protected by fiber as shown in Fig. 191, they may be used.

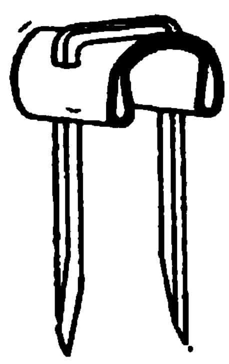


Fig. 191

In addition to the types of battery connectors already described, the type shown in Fig. 192 is often used in vaults and cupboards.

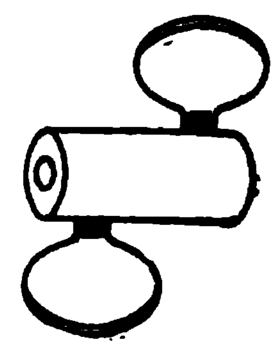


Fig. 192

428. Wiring in Relay Shelters: As indicated in Fig. 71, the *solid* wires from the trunking are usually lead into the relay boxes and connected to the lightning arresters or terminals. From the arresters or terminals, *flexible* leads are carried to the relay.

It is only possible to allow a small amount of slack in the solid wires in relay shelters, on account of the inconvenience of handling and tracing due to lack of space, but where the size of the trunking leading into a relay box permits, some slack may be left in a fold at that point. As the flexible leads are short and may readily be replaced, only sufficient slack is allowed to permit the relay to be tilted for inspection.

429. Where connections are to be made to binding posts or screws with flexible leads, the strands should be soldered together to insure a good connection.

430. When the flexible wire is to be employed with a binding post similar to that shown in Fig. 183, the wire is cleaned, the strands then twisted compactly together and soldered, preferably by dipping, the surface finally being cleaned as when making joints. When thus prepared the wire presents the appearance shown in sketch A, Fig. 193.

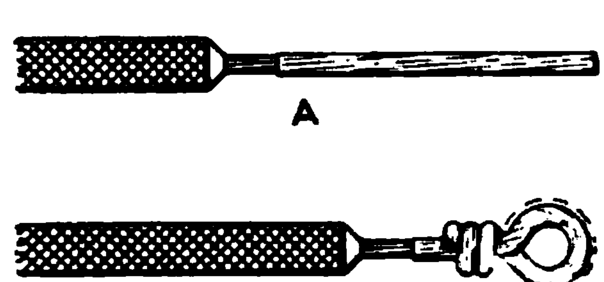


Fig. 193

With binding posts requiring that the wire be passed around the screw, the form of loop illustrated in sketch B, is very frequently used. The wire is formed in the manner shown and soldered as just described. The dotted circle indicates the position of the binding nut, showing that the turns are formed so that they will not come beneath it, and thus tend to prevent a good contact.

After the soldering is completed the end of the insulation is frequently wrapped with one layer of friction tape and painted with P. & B. compound, the tape extending as close as possible to the binding post. This taping is applied to prevent the insulation from slipping back, and exposing wire which might come into contact with other terminals.

431. Other methods sometimes used to make connection between flexible wires and binding posts, are shown in Fig. 194, these brass or copper lugs* being soldered to the wire and then attached to the binding posts.

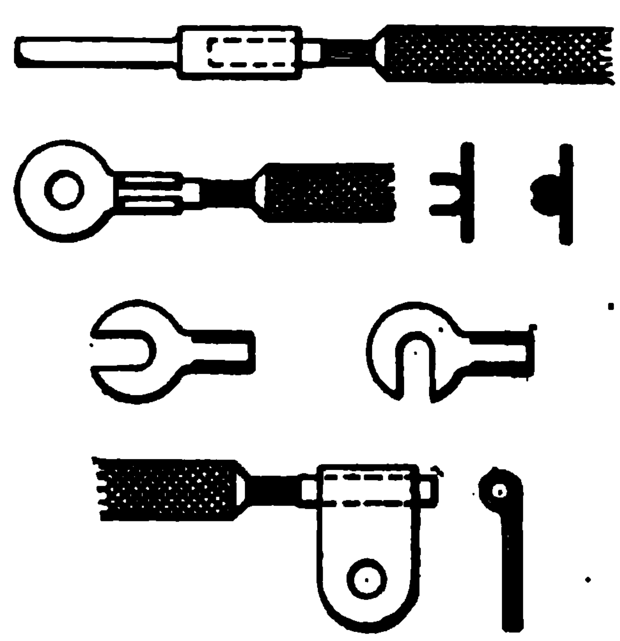


Fig. 194

432. Wiring in Buildings: In many instances the solid wire from the outside trunking is brought into the tower to the lightning arresters or terminal boards. In other cases, as before noted, office wire is used in the tower, being connected to the rubber covered wire where it enters the building.

433. When not placed in trunking, the interior wiring is secured to the wall by wooden or porcelain cleats spaced from 2 to 4 ft. apart. To obtain a neat appearance the wires are stretched tightly between the cleats, and in the case of office wire, *snubbed* in the manner shown in Fig. 195, at the end of a run, to keep the wires taut. When turning corners the cleats should be arranged as shown in Fig. 196.

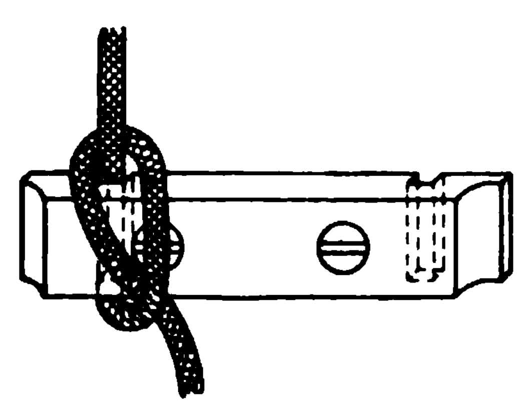


Fig. 195

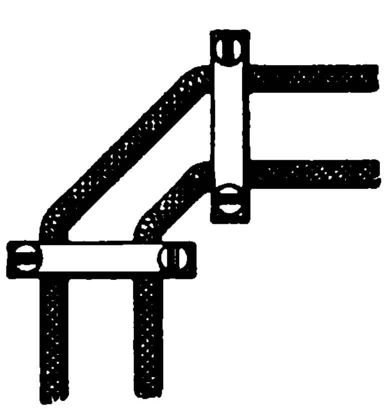


Fig. 196

434. Where wires are to be run across floor joists which are not covered with ceiling, a *running-board* should first be nailed

*Also called *terminals*.

to the floor joists upon which to run the wires to protect them. A view of this looking upward, is shown in Fig. 197.

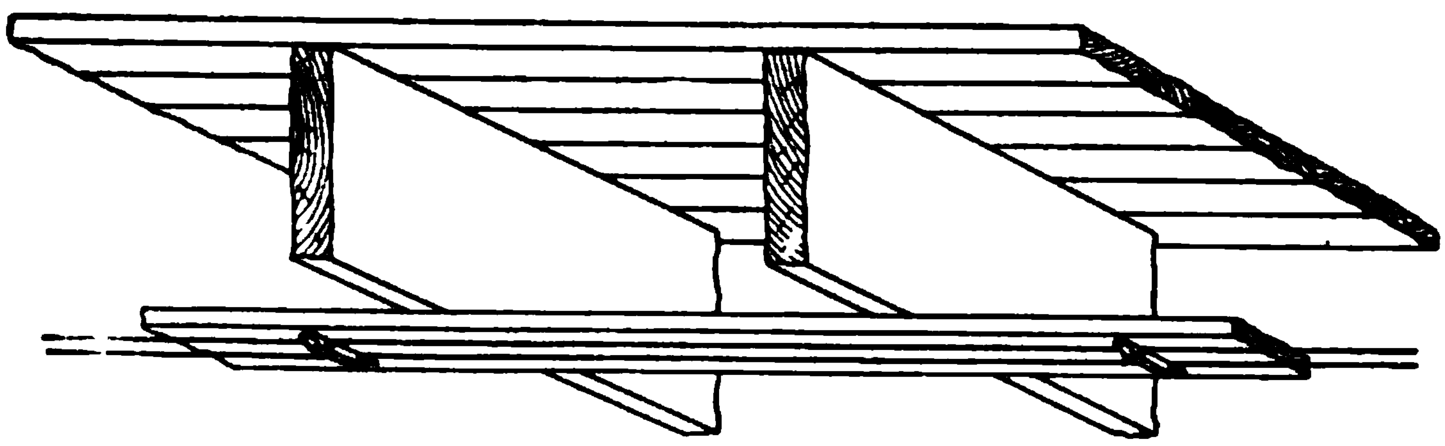


Fig. 197

435. Where office wire is connected to binding posts or screws, a spiral consisting of about 1 ft. of wire wound upon a pencil, is allowed.

436. Marking Wires: All wires should be marked to indicate their function.* Various forms of tags are employed for this purpose, the use of fiber tags, a type of which is shown in sketch A, Fig. 198, being considered very good practice.

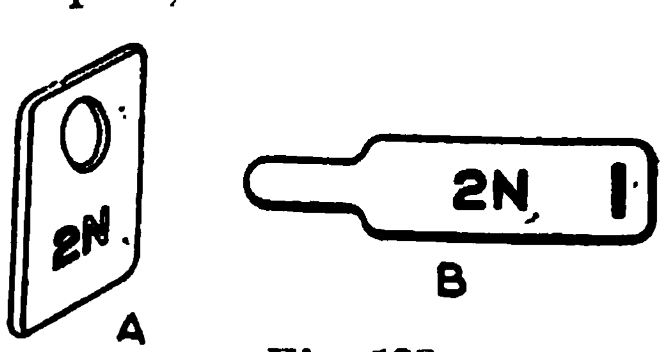


Fig. 198

Linen tags about $1 \times 1\frac{1}{2}$ in. are frequently used, the wire designation being marked on it with water-proof ink.

Brass, copper, lead, aluminum and other metal tags, a form of which is shown in sketch B, are used to some extent, although trouble, due to grounds and crosses caused by them, is sometimes experienced.

On some roads it is the practice to stamp the wire designation on the brass terminal strips (Fig. 71). Steel numbers or letters are employed for this purpose and are also used to stamp fiber and metal tags.

437. Fiber tags are generally attached to the wires with $\frac{1}{16}$ in. tarred yacht marline, although in some instances the wires are passed through the holes in the tags, while in other instances, the tags are secured beneath check nuts on binding posts. Metal tags are either wrapped around the wires, or attached to them

*Systems of wire numbering and lettering are described later.

with marline or fine iron wire. Linen tags are usually secured with fine strong twine.

438. It is good practice to tag all wires in relay shelters, at lightning arresters when separated from the relays, in slack boxes, and in battery shelters except in chutes where it is done only when necessary to distinguish the polarity, for instance in the case of polarized circuits.

In the case of batteries for two or more circuits being placed in one chute or in a number of chutes located close together, it is desirable to distinguish between them by marking the elevators or suitably tagging the wires.

In relay shelters the tags are generally fastened to the solid wire.

439. When disconnecting the wires for any purpose, care should be taken to keep the tags with the wires to which they belong. Linen tags become soiled and disfigured by handling and should therefore be renewed as circumstances require.

440. Maintenance: When run above ground, trunking is sometimes accidentally broken and the wires injured, as a result of derailments, etc. In some cases, when the insulation is only slightly injured, it may be repaired by being thoroughly cleaned and dried, and then covered with insulating and friction tape, and P. & B. compound, as the case requires, being sure that the resulting insulation is equivalent to that of the rest of the wire. However, if badly damaged it is generally desirable to replace the wire, to the nearest slack boxes.

Oil should not be allowed to get on to the insulation of rubber covered wire as it is likely to soften it.

BATTERIES

441. After a track circuit has been installed a current or voltage reading should be taken at the terminals of the relay to insure that the arrangement of batteries (and artificial resistance when used), is giving the desired amount of energy.

The general directions for the installation and maintenance of batteries, given in *Magnetism and Electricity,* apply to their use in track circuit work. The special points in relation to each type, as used in this connection, will now be considered.

442. Gravity Batteries: When installing gravity batteries the method of procedure depends upon circumstances, as follows: First, if sufficient time is available, the cells may be set up with water, and each of them left on short circuit. As the cells pick up slower at a low temperature, more time must be allowed during cold weather. Second, in case they are required for service at once, zinc sulphate solution may be taken from other cells which are in operation, but if none are within reach, dilute sulphuric acid may be used.

443. After a gravity battery has been set up, it is not desirable to connect it to the track any considerable length of time before connecting the relay, as the small discharge through the ballast, especially in case of high ballast resistance, would not provide the necessary work required by this type of battery to keep it in good condition.

444. *Test.* The charts shown in Figs. 199-202 represent the action of two cells of gravity battery connected in multiple to a normally closed track circuit employing a 4-ohm relay. These results were obtained from a laboratory test in which the maximum ballast resistance was taken at 10 ohms and the minimum at 2 ohms. Owing to the variety of conditions governing the operation of similar track circuits the results obtained from an actual test on any one circuit, would not apply exactly to any other circuit, and therefore this test will convey a fair idea of the action of such a battery on this class of work.

445. Ordinary 6 x 8 in. cells were employed, using a 4 lb. circular zinc, and 4 lbs. of blue vitriol in each cell. On some roads other types of zincs are used, and in some instances less vitriol is employed. However, such differences would not materially affect the results obtained, except when less vitriol is used, the life of the cell is of course, shortened.

The battery was started with water as the electrolyte, no white vitriol solution or sulphuric acid being used, and was left on short circuit for about 4 hrs., after which it was connected into the circuit, the track being shunted for about 3 min. every half hour, to represent train movements.

446. Curve B, Fig. 199, indicating the current output from the battery when the track is unoccupied, shows the effect of variations in the ballast resistance. It will be noted that between the 13th and 17th days, during which time the ballast resistance varied between its maximum and minimum points, the current output varied between 275 and 480 mil-amperes. This of course represents the effect produced by wet weather.

447. Curve C, representing the current through the relay, shows, during periods of wet weather when the ballast resistance is low, that although as indicated by curve B the output from the battery is considerably higher than in good weather, the current received by the relay is lower, due of course, to the increased leakage of current from rail to rail.

448. The curve shown in Fig. 200 represents the readings that would be obtained on a voltmeter connected across the track. It will be observed that this voltage drops during wet weather, as in the case of the current through the relay.

449. Curves D and E, Fig. 201, represent the line of demarcation and the specific gravity of the white vitriol solution expressed in Beaumé scale.

It will be noted that curve D is not started until the 4th day, as prior to this time the line of demarcation was not well defined.

The sharp drops in curve E, indicate the dates on which the solution was weakened, the zincs being cleaned on the same dates. The hydrometer reading given for the 11th day represents the reading which is obtained when the cells are first set up with one pint of white vitriol solution at 30 deg. Beaumé. As it is the general practice when maintaining, to renew the cells in this manner, the dates for weakening the solution and cleaning the zincs, were calculated from this date.

Fig. 199

Fig. 200

Fig. 201

The variation in the line of demarcation is shown graphically in Fig. 202, this of course, agreeing with curve D, and also indicating the consumption of the blue vitriol.

4th to 9th Day 18th Day 27th Day 36th Day

54th Day 63rd Day

Fig. 202

450. *Maintenance.* Where the ballast resistance is low and consequently the resistance of the relay is low, the current consumption is such that it is often necessary to attend to the batteries every two weeks.

It is the usual practice to renew all the cells of a battery at the same time, this of course, requiring that they all be repaired* at the same time. In some cases however, with a two-cell multiple arrangement, the cells are renewed alternately, being set up with water, no white vitriol solution being used. When one of the cells is renewed the other is repaired. Thus it is apparent, that while one of the cells is picking up, the efficiency of the other is high, and therefore a more uniform output is obtained. than when both cells are renewed at once.

451. In battery arrangements similar to E and J, Fig. 88, where the cells do not exhaust uniformly, it is the practice

*Zincs cleaned and solution weakened.

to change the relative positions of the cells when renewing and repairing, so that all of the cells during their life, will be subjected to the same amount of work.

452. Considerable care should be taken to prevent the formation of stalactites on the zinc as the short circuit which sometimes results will in multiple arrangements, short circuit the entire battery through one cell.

453. In order to avoid cracking the jars on account of difference in temperature, it is desirable especially in cold weather, to set them upon a board when removed from their shelters, instead of setting them on the ground.

454. In extreme cold weather it is sometimes advantageous to use warm water when renewing or repairing cells. In this connection care should be exercised to avoid cracking the jars, when pouring warm water into them, by first partly filling the jar with cold water.

455. It is desirable to keep a record of the dates when the cells are renewed and repaired, to avoid confusion as to when they should again receive attention. It is also well to record the dates when new zincs are installed, so that they will not be carried unnecessarily when renewing.

As it is considered good practice to keep at each battery location, the materials necessary to set up a complete cell, it is also convenient to keep a record of such material.

It is advisable to note on the record any special conditions in regard to the performance of the batteries, such as hydrometer readings, etc., which may be of value in determining when each will again require attention.

456. Caustic Soda and Potash Batteries: On account of the low internal resistance of these types of batteries, it is customary, as before stated, to use artificial resistance in series with them. The value of this resistance is sometimes governed by the length of the circuit, but in most cases a resistance of about ½ ohm in each circuit, has proven satisfactory.

Whereas, owing to their comparatively high internal resistance, gravity batteries should generally be located as near as practicable to the point where they are connected to the track, caustic soda or potash batteries may be located at a considerable distance from the point of connection, the resistance of the wire being calculated as a part of the artificial resistance.

As the polarity of these batteries is liable to reverse under certain conditions, their use on polarized track circuits is sometimes considered objectionable.

457. As delays to traffic or dangerous conditions are likely to arise due to disconnecting the battery from the track, it should be assured before taking this step, that no such conditions will result. As a rule when renewing, but one cell is disconnected at a time, in series arrangements a jumper first being applied.

In two-cell multiple arrangements a single cell will usually be sufficient to hold up the relay but in some cases may not be sufficient to pick it up if released. Therefore in such instances, both cells should be connected to the track to insure the operation of the relay, immediately after the passage of a train. Of course, if the circuit is occupied by a train the entire battery may be disconnected if again connected before the train passes off the circuit.

458. When the spare material for setting up a complete cell is available, it proves of considerable advantage when renewing, to set up this cell and substitute it for one of the cells of the battery, the cell which is removed becoming the spare cell. Thus a part of the battery is disconnected for the shortest possible time.

459. Before lowering the elevator into an iron chute an inspection should be made to insure that the connections will not come into contact with the sides of the chute, thus causing a ground or a short circuit.

After any work has been done on a battery, it is very desirable as a check, to connect a voltmeter or other suitable testing in-

strument across the track, to insure the proper working condition of the battery.

460. Storage Batteries: It is the common practice to install 80 ampere-hour storage cells where it is desired to supply one, two or three track circuits from the same battery. Cells of larger capacity are used in batteries feeding a larger number of circuits.

In batteries which are floated on generator circuits, smaller capacity cells are sometimes used.

461. An installation of storage batteries together with adjustable resistances and charging switch, is shown in Fig. 179. It will be observed that the resistances are of the type shown in Fig. 44.

462. It is the usual practice to connect storage batteries at different locations in series with each other when charging. When so arranged it is desirable to have a double-throw cut-out switch at each location, connected as shown in Fig. 203, so that the charging line may be completed through it, thus allowing the batteries to be disconnected from the line, without interrupting the charging of other batteries in the same circuit.

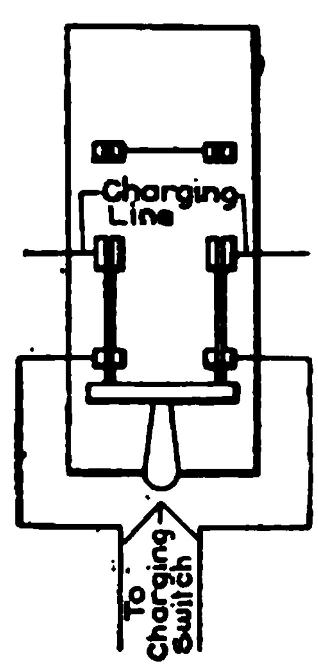


Fig. 203

The installation of *charging lines* is treated later.

463. As the use of artificial resistance is always necessary with storage batteries they may be located at some distance from the point where connection is made to the track, as explained in connection with caustic soda or potash batteries.

Fuses when used with storage batteries are mounted on slate or porcelain bases, and so located that they may be easily replaced if blown.

464. Storage batteries used on track circuits are generally charged daily in order that a good reserve for emergencies

may always be available. The charging is frequently done at night, thus allowing the charging line to be dead in the day time when inspection and other work about the batteries is usually done. In this connection it is well to remember that exposed flames (lanterns, etc.) should not be brought close to the cells when gassing.

As the capacity of storage batteries is decreased by extreme cold weather, it may be advisable to charge them more frequently at such times.

Records of the hydrometer readings and voltage of each cell should be made regularly. This is often done each day when the charging switch is changed, although the voltage test is sometimes taken at less frequent intervals.

465. The bare resistance wire of adjustable resistances, Figs. 43-44, is liable to become corroded, especially if exposed to the fumes of storage cells, and therefore whenever changing the adjustment, the surface of the wire should be cleaned.

GENERAL MAINTENANCE

TESTING

466. Instruments: It is desirable to have a *mil-ammeter,** a *low reading voltmeter** and a *magneto* for testing in connection with track circuits. A *volt-ammeter* is commonly used, although some of the tests require the use of separate instruments.

Another instrument used in testing track circuits, is an electro-magnet wound to about the same resistance as the track relays with which it is used, the coils being well protected and the armature so arranged that its operation may be readily observed. A tester of this type is illustrated in Fig. 204. It may be used in place of a voltmeter where it is necessary to indicate the presence of voltage but not the exact amount. An estimate of the voltage at the terminals of the tester may be made, by judging the strength with which the armature is attracted.

Fig. 204

*See Arts. 311 and 316.

467. Ballast Resistance:* When measuring for ballast resistance, weather conditions should, of course, be considered.

If it is desired to ascertain the ballast resistance of a length of track, it may be done after the track has been bonded and the insulated joints installed, by the use of a mil-ammeter,

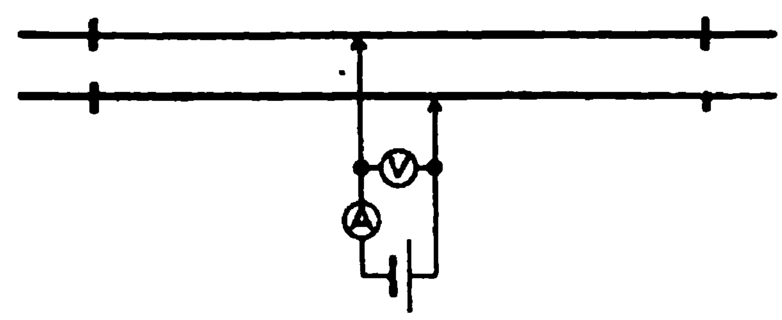


Fig. 205

voltmeter, and one or more cells of battery connected at the center of the circuit, as shown in Fig. 205, the resistance being calculated by applying Ohm's Law (Art. 316).

The object of connecting the meters at the center of the circuit is to minimize the effect of resistance in the rails and bonding. As any unusual resistance in the bonding may materially affect the results obtained, it is desirable when accuracy is required, to take a voltmeter reading at each end of the track, while the battery and ammeter are still connected, any considerable discrepancy in the voltmeter readings indicating unusual resistance in the bonding (Art. 474).

468. This method may of course, also be employed when it is desired to find the ballast resistance of an ordinary normally closed track circuit, the relay being disconnected and the track battery used in making the test.

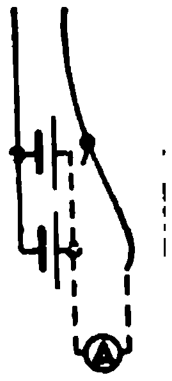


Fig. 206

469. When taking current readings at a multiple battery, it is well to disconnect the wires from all the zincs, and connect them to the meter as shown in Fig. 206.

470. If, as is often the case, it is undesirable to have the relay disconnected long enough to make this test, the ballast resistance may be obtained from current readings taken at the battery and relay, using formula (2) (Art. 114), arranged as follows,

$$n = \frac{ir}{I - i}. \qquad (13)$$

*The resistance of the rails and bonding has not been considered.

471. **Problem.—If in a normally closed track circuit using a 4-ohm relay, current readings of 125 and 375 mil-amperes are taken at the relay and the battery respectively, what is the ballast resistance?**

Answer.—2 ohms.

472. To find the ballast resistance of a normally open track circuit the mil-ammeter should be connected in place of the relay, and the voltmeter connected as in Fig. 205.

473. A *Wheatstone bridge* may of course, be used for making resistance measurements, but the methods described are sufficiently accurate for most purposes.

474. Bonding: If it is desired to test the conductivity of the bonding in a track circuit, voltage readings should be taken from rail to rail, beginning at one end of the circuit, at intervals of about twenty rail lengths on long circuits, and at more frequent intervals on short circuits. If considerable difference is noted between two adjacent readings it indicates that there is unusual resistance in the bonding between these points and to locate this resistance, additional readings should be taken between them. When a joint is found, on each side of which the readings show a marked difference, the meter should be connected across it and if any appreciable deflection is noted, it is of course an indication of considerable resistance in the bonding. If the bond wires are not broken, unusual resistance at any of the pins or plugs may be located by the same method.

If a low reading voltmeter is not obtainable a mil-ammeter may be used in the same manner. However, as the resistance of the mil-ammeter is very low, connecting it across the rails will of course, shunt the relay, being likely to cause delay to traffic and sometimes dangerous conditions, which should be guarded against.

475. Poor bonding is often very difficult to locate, because the path through the splice plates may at times, carry the current satisfactorily, and thus with defective bond wires, the conductivity of this path may vary considerably in a very few

hours causing intermittent failures and possibly being good while a test is conducted.

If the condition of the bonds at any joint is doubtful, such as in a crossing where they cannot readily be inspected, the meter should be connected across the joint and the rails rapped sharply with a hammer. If the reading of the meter is altered appreciably it is an indication that the bonds are defective.

476. Broken Rail Protection: If it is desired to test the efficiency of a track circuit for detecting broken rails, it may be done as follows: An insulated rail joint is installed in one of the rails, usually at the center of the circuit, and bridged with bonds made in two parts which are joined by suitable connectors so that they can be readily opened or closed. Thus the effect of a broken rail may be reproduced at any time by opening these bonds, and measurements then taken will indicate what effect a broken rail at this point would have on the relay.

477. Fouling Sections: As the efficiency of multiple fouling sections, Figs. 127-128, is dependent upon the connection made by the jumpers and the bonding of the siding rails, frequent inspection is necessary.

Aside from noting the condition of these connections, the following test should be made when circumstances permit. If the operation of the relay can be readily observed, a jumper connected as shown dotted at A, Fig. 207, close to the insulated

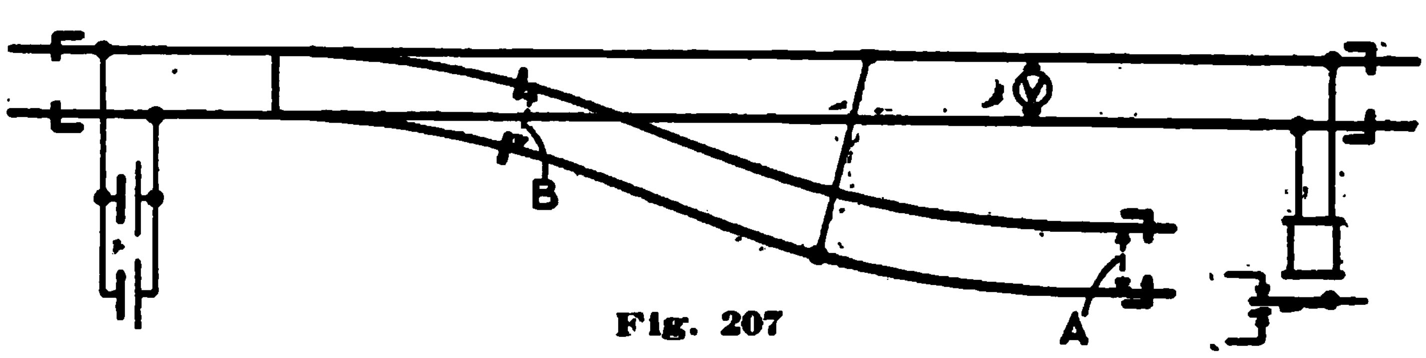


Fig. 207

joints, should shunt the relay, this indicating that the jumper and the bonding of a portion of the fouling section is in good condition. The jumper is then connected as at B to test for the balance of the bonding.

If the operation of the relay cannot conveniently be noted, a voltmeter or other suitable instrument should be connected

as shown, and its operation observed as a substitute for the relay.

With the double jumper arrangement, Fig. 128, in addition to the tests at the ends of the fouling section, it is well to span the siding rails with the jumper at the center.

If on account of density of traffic or for any other reasons, it is not desirable to shunt the relay, readings taken with the voltmeter spanning the siding rails at A and B, instead of the test jumper, should agree with a reading taken on the main track, to indicate that the connections are in good condition.

478. When testing the series fouling section, Fig. 129, either of the tests just described may be employed to indicate the condition of the bonding in the siding rail between joints C and D. Insulated joint A should be tested in the manner described in Arts. 311-316.

479. Pole Changers: As resistance in the contacts of pole changers may materially affect the operation of polarized track circuits, these contacts should occasionally be tested by measuring the current, and the drop in voltage across them, and calculating their resistance by the use of Ohm's Law.

If a low reading voltmeter is not obtainable, the resistance may be judged by comparing the readings of a mil-ammeter bridging the contacts, with readings taken when the contacts are in good condition.

In case of unusual resistance in the contacts they should be cleaned, emery cloth being employed for this purpose.

FOREIGN CURRENT

480. One of the most troublesome causes of failures is the presence of *foreign current* in track circuits.

Such current may not only oppose the battery and de-energize the relay improperly, thus causing delays to traffic, etc., but it may be of sufficient strength to energize the relay

when the track is occupied, which of course, is liable to produce a very dangerous condition.

481. Sources: The most common sources of foreign current are electric roads and power and lighting circuits, situated in the same locality as the track circuits, although in some instances it is difficult to trace its origin.*

The stray propulsion currents from electric roads, are probably the most important factor to contend with in track circuit operation.

482. Testing: Where there is reason to suspect the presence of foreign current in a circuit, it may sometimes be detected by disconnecting the battery and inserting a mil-ammeter in series with the relay, readings upon which will indicate the strength of stray currents. If no reading is obtained, it cannot be considered as conclusive evidence of the absence of foreign current, owing to the fact that these currents often fluctuate considerably, and whereas at any certain time there might not be sufficient current to show a deflection, a few minutes later there might be more than enough to operate the relay. In many instances the polarity of the stray currents is also a variable, changing frequently in the same track circuit and thus requiring close observation of the action of the meter.

483. If at any time an exceptionally high voltage reading is obtained at any point in the circuit, it should if possible be traced, as it is generally an indication of the presence of foreign current.**

484. Remedies: Whenever foreign current is found to be present in a track circuit, measures should be taken to overcome or at least minimize its effect. There are several methods employed to obtain this result.

As stated in Art. 145, it is generally desirable not to connect a number of long track circuits together, either to a common source of energy, or as single rail circuits. It is apparent that while the foreign current in one circuit might not be strong

*See Art. 245; storage battery effect of treated ties.
**See Art. 319.

enough to cause any trouble, if a number were connected together the combined effect would be likely to produce bad results. In this connection long circuits are sometimes cut into two parts.

485. The rails should be kept as well insulated from the ballast as possible, and high resistance maintained at the insulated joints,* in order to make it difficult for foreign current to get to the rails. As mentioned in Arts. 41-43, interlocking pipe and wire lines are insulated from the rails, to assist in this connection.

It should be understood that the potential causing the stray current to flow, does not *break down* the insulation, but simply causes current to *leak* through or across it.

486. The bonding should be kept in first class condition so that the wheels will, at any point on the circuit, have their maximum effect in shunting the relay. It will readily be understood that in case foreign current enters a normally closed track circuit near the relay, any increase in resistance between the relay and the wheels on account of poor bonding, will cause an increase in the amount of stray current flowing through the relay, thus tending to energize it improperly.

If there are any cutouts (Figs. 122, 135 and 136) in a track circuit, voltage measurements should frequently be made at each end of them; if any unusual difference of potential is discovered it indicates that the resistance in the jumper has increased, and the cause should at once be located and removed.

487. By using a relay of as high resistance as possible, additional protection may be secured against foreign current, on account of the comparatively high voltage required to operate it.

488. When there is a grade crossing of an electric road and a road on which there are track circuits as in Fig. 208, a low resistance path should be provided for the propulsion current

*See Arts. 262-265 and 306-308.

return. In addition to the regular bonding of the frogs, it will be noted that a heavy cable spans the crossing, being connected to both rails of the electric road, and all portions of the frogs connected to it. Therefore in case of poor bonding, a very low potential difference will be maintained between any two parts of the frogs, and very little if any current is likely to be forced on to the track circuit rails.

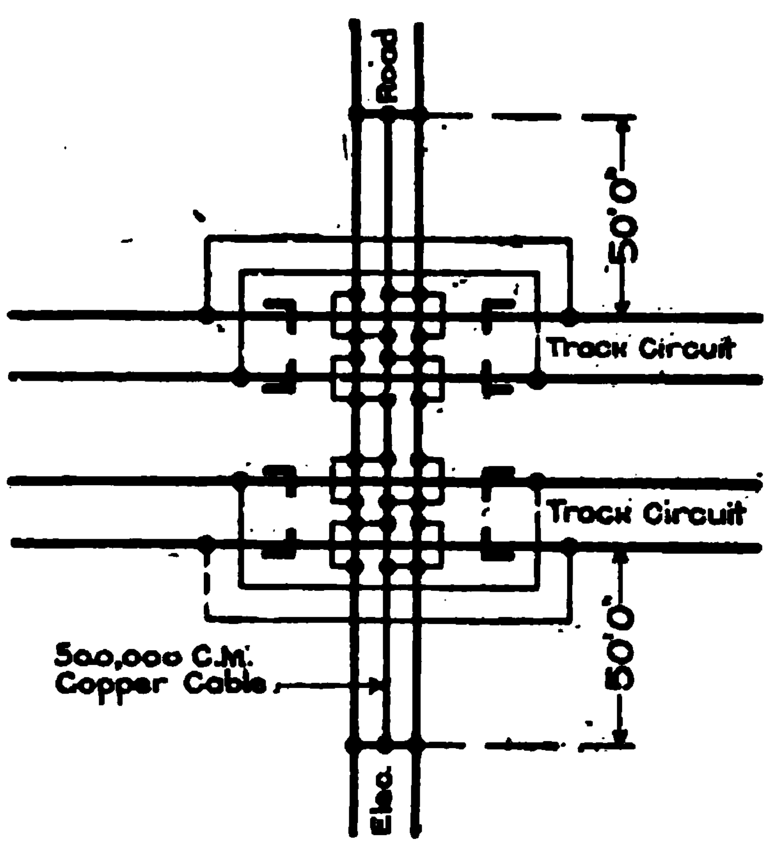


Fig. 208

489. It will be noted that the track circuits are carried around the frogs through jumpers, which are well insulated from the rails, sometimes being carried overhead. These jumpers where placed in trunking as well as the taps between the frogs and the large cable, are made of rubber covered wire, not smaller than No. 9 B. & S. G.

490. In some instances good results have been obtained by using the arrangement shown in Fig. 208, with the exception that instead of carrying the track circuits through jumpers across the electric road, the circuits are terminated on each side of it, the track batteries being installed at this point, and feeding in the same direction as the foreign current, if its direction can be definitely determined.

491. It often happens that the electric road runs up on both sides, close to the tracks on which the circuits are installed, but does not cross them. In such instances, a high potential difference is apt to be maintained between the two portions of the electric road, which will probably force current through the ground to the track circuit rails.

492. When considerable potential difference is found to exist between the rails of a track circuit, caused in the manner just

described or in a similar manner, it may be found advantageous to insert a transposition, Fig. 209, at the point of highest poten-

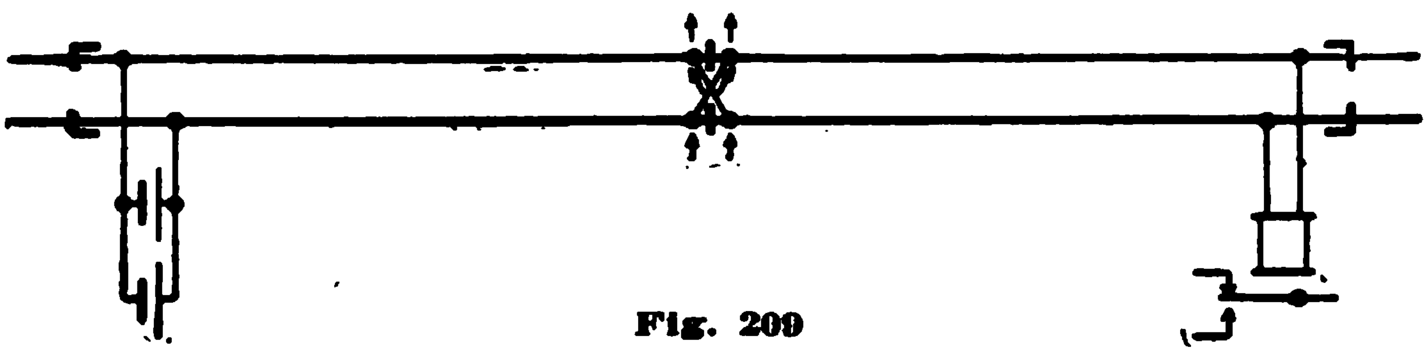


Fig. 209

tial, which is found by taking voltage readings with the battery and relay disconnected. Thus a low resistance path is provided between the rails, the foreign current passing from rail to rail through the jumpers as shown by arrows, instead of through the relay. When installing transpositions the arrangement of the insulated rail joints should of course, be governed by the resulting dead section (Art. 299). If the jumpers are made of bare wire they should be well separated to prevent accidental shunting of the relay.

At bridge crossings where the electric road passes under the track, and the trolley wire is supported by the steel structure of the bridge, current from this wire may cause trouble on track circuits on the bridge, on account of defective insulation of the wire from the structure. To guard against such trouble it is customary to ground the bridge structure, thus providing a return path for the trolley current in case of leakage.

493. As mentioned in Art. 182, the use of a multiple clearing relay often assists in overcoming the effect of foreign current. For instance in Fig. 210, with a broken rail or poor bonding at

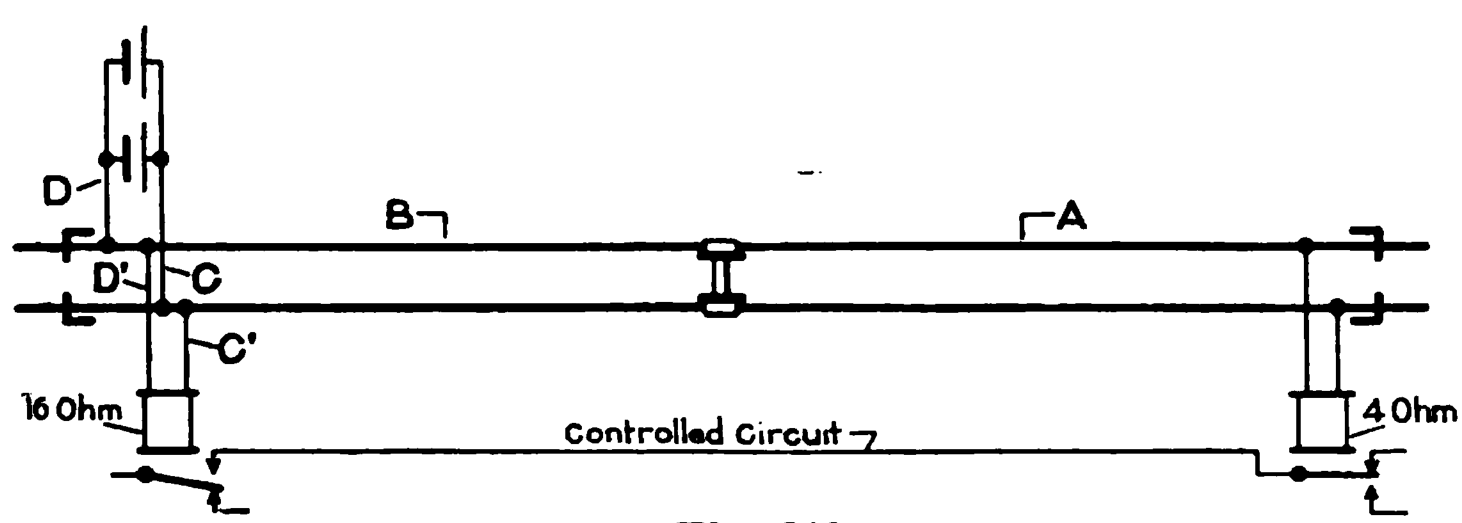


Fig. 210

point A, and the wheels in the position shown, the 4-ohm relay might be energized by foreign current entering the circuit near

it. But by installing the 16-ohm relay and carrying the controlled circuit through contacts on both relays, the 16-ohm relay would be de-energized and the controlled circuit kept open. However, with poor bonding also at point B, the 16-ohm relay, with the wheels in the position shown, may be energized by the track battery, and thus may fail to give the desired protection.

The differential clearing relay, Art. 224, may also be used in this manner.

494. When employing clearing relays as just described, the connections of the battery and clearing relay to the track, should be made by independent wiring, for in case either pair C and C′ or D and D′, Fig. 210, are joined and connected by a single lead to the rail (a method of installation sometimes followed), this lead may break or make poor connection, in which event the clearing relay would be likely to be energized continuously.

When the differential relay is used (Fig. 121), the coils of the clearing relay should be connected to the rails separately, the low wound coil being in series with the battery.

495. When electric roads run parallel to the tracks upon which the circuits are in use, it is often found desirable to provide a path for the stray current. An arrangement available for a short isolated track circuit is shown in Fig. 211, in which the foreign current is carried past the circuit, by a jumper of suitable capacity.

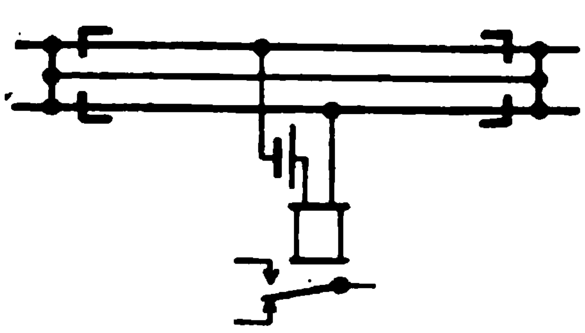


Fig. 211

496. The arrangement illustrated in Fig. 212, in which single

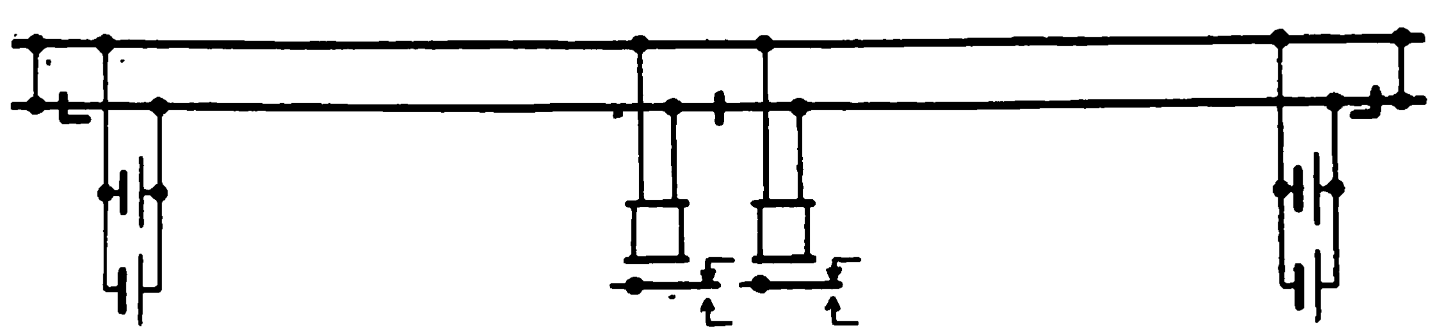


Fig. 212

rail circuits are used, may occasionally be employed to advantage. It will be observed that the dead rails are bonded

together by jumpers and that the common rail conducts the stray current past the circuits.

497. It is generally conceded that the most efficient means to overcome the effect of foreign current, is to employ alternating current as a source of energy using a relay not affected by direct current or by foreign alternating current.*

RECORDS

498. When making tests it is generally desirable to keep a record of the results obtained. For instance, if making a voltage test as described in Art. 474, the readings in the order taken, and any other information of value, such as the battery arrangement, type and resistance of relay, weather conditions, etc., should be recorded.

If it is desired to study more in detail the drop in voltage, it will be found very convenient to plot a curve from the readings taken. This will not only indicate at a glance any unusual conditions, but will give a very fair idea of the voltage at points between those at which the readings were taken. On such a chart, the distance from the battery would be shown at the bottom in feet or rail lengths, the voltage appearing at the side.

It will sometimes be found advantageous to record tests of fouling sections, insulated joints, relay contacts, pole changer contacts, etc., which are of value for comparison when making inspections.

FAILURES

499. Normally Closed Track Circuits: If it is discovered that a normally closed track circuit has failed to pick up the relay, testing for the trouble may be started at practically any point in the circuit by taking a voltage reading across the rails. If a normal reading is obtained it indicates that the battery is in good condition and also the portion of the circuit between the battery and the point where the test is being made. This test should now be repeated moving towards the relay.

If a sudden drop is noted between two adjacent readings, it

*A. C. track circuits are treated later.

will of course, indicate that between the points where the readings were taken, there is unusual resistance in the circuit, such as defective bonding or high resistance in a jumper. For instance, if the voltage readings taken at each end of a jumper similar to that shown in Fig. 122, vary considerably, a test jumper should be attached to the rails at the same points as the permanent jumper, being connected in multiple with it. If after the test jumper is connected the voltage at each end is about the same, it is of course, an indication of resistance in the permanent jumper.

If no special drop is noted before reaching the relay, a test should be made at its terminals, at which point a good reading will of course, indicate a defective relay. A low reading at this point will indicate high resistance in the relay leads. A test jumper should therefore be connected in multiple with one of them, the operation of the relay indicating that there is high resistance in the permanent lead.* If the relay does not operate it is an indication that this lead is in good condition and the other lead defective, the latter now being tested in a similar manner.

500. If when the voltage is first taken across the rails an unusually low reading is obtained, these tests should be repeated, moving towards the battery. If no trouble is found when the battery is reached, the voltage on the rails still being low, then a high reading across the battery terminals, indicates resistance in the leads to the track, which should be located by using the test jumper as described in connection with the relay leads, the voltmeter being connected across the rails, to indicate when the jumper spans the defective lead.

Fig. 213

Assuming that the voltage is still low when taken at the battery terminals, and that the battery appears to be in good condition, then one side of the battery should be disconnected from the track and its voltage again measured with the meter connected as shown in Fig. 213, a low reading in this instance indicating that the battery is not in working condition. To definitely locate such trouble the cells should be tested separately.

*If there is any doubt as to which of the rails either binding post is connected to, the test jumper should be touched to each post.

A high reading may sometimes be obtained when batteries are disconnected, even if they are in poor condition, owing to the rest they receive while their connections are being changed for the test. To insure that the reading shows the true condition of the battery, the latter should be short-circuited for about a minute,* after the meter has been connected, removing the shunt while the meter is still in circuit. A high reading obtained *directly* after the shunt is removed is usually an indication that the battery is in good working order.

A current test instead of a voltage test may be made by connecting a mil-ammeter in place of the voltmeter as shown in Fig. 213, each cell being tested *separately*. Of course, when making tests of caustic soda or potash or storage batteries, the artificial resistance must be kept in series with the meter.

The output of primary batteries, especially gravity cells, which remain out of chutes for any great length of time during cold weather, is likely to be considerably reduced and this should of course be taken into consideration when testing.

In case there is no trouble found with the battery, the next step in the test, is to obtain a current reading with the mil-ammeter connected as in Fig. 206. Under these conditions a high reading should be obtained, indicating that there is a shunt on the circuit.

The next step is to locate and remove the shunt, inspecting the ballast, examining and testing if necessary all insulated joints separating rails of opposite polarity, switch, front, and lock rod insulation, wedge blocks, etc., and inspecting connections wherever short circuits might occur.

If after making a close examination the shunt is not located, a current measurement should be taken at the relay. A high reading will indicate that the relay is defective and a low reading, that the relay is in proper working order, the shunt having been overlooked.

As the test for insulated joints (Arts. 311-316), does not indicate the condition of the end post, it may now be desirable to take apart the joints which were tested, and inspect this portion of them.

*The artificial resistance should of course, be kept in series with storage batteries during this test.

If this does not discover the trouble, the switch, front, and lock rod insulation may be given a more thorough examination, by disconnecting one end, and if dry, testing with the magneto. Another method of testing the rods is to connect the voltmeter across the rails, noting the effect when the rods are disconnected.

Assuming that the foregoing inspection has not located the trouble, the bonds should be cut and the plates removed from a joint at the middle of the circuit and a voltmeter reading taken across the rails on the side nearest to the battery, as shown in Fig. 214. A low reading will indicate that the

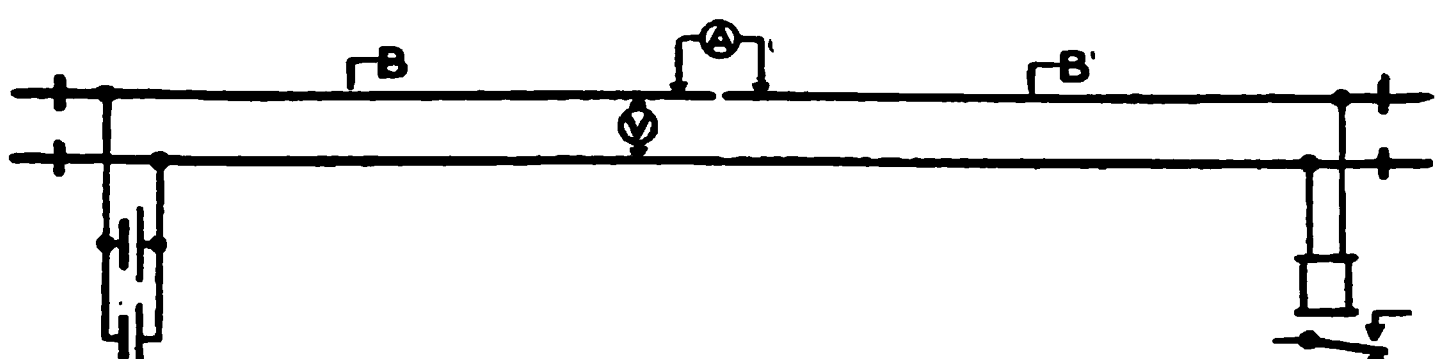


Fig. 214

trouble is between the open joint and the battery and a high reading, that it is on the other side of the open joint. In case the trouble is in the direction of the relay, a mil-ammeter connected around the open joint as indicated, will act as a check on the voltmeter test by giving a high reading.

The next step after replacing the joint and connecting the bonds, is to open up another joint, midway between this joint and the end of the circuit toward which the trouble appears to be, that is either at B or B′, conducting the test in a manner similar to that just described. By repeating this operation the shunt will be traced to a short length of track, which can then be examined very closely.

In case the trouble appears to be due to low ballast resistance possibly on account of the ties being saturated with water, as might be indicated by moderate readings when testing at the open joint in the middle of the circuit, it may be of advantage to make a ballast resistance test.

The possibility of a shunt occurring in a fouling section, should not be overlooked.

501. With the tests described in Arts. 499-500, it is assumed that there is only *one* source of trouble in the circuit. It is

however, quite possible that there are *two or more* causes of failure, and therefore considerable care and judgment will sometimes be required in the use of the meters.

502. Occasionally a circuit will be found in which the relay is receiving considerably less than its normal amount of current, and will be likely to fail under severe conditions, as for instance continued wet weather. In such a case the voltage at the terminals of the relay should be taken to insure no increase in its resistance, which would of course, be indicated by a high reading. A low reading indicates either low ballast resistance or other shunt on the circuit, or poor bonding or other series resistance. The next step is to determine if the trouble is due to a shunt or to series resistance, the method of procedure being governed accordingly.

503. *Intermittent Failures.* Intermittent failures are those in which the cause of trouble varies in its effect upon the circuit. One cause of such failures is described in Art. 475.

As a close inspection made when the circuit is working properly may not discover the trouble, it is very desirable to be present when the circuit fails, in order that its condition may then be tested. On this account it is well to note if the failures constantly recur at any particular time of the day, as is occasionally the case.

504. The expansion and contraction of the rails due to changes in temperature may alter the conductivity of a poorly bonded joint (Art. 475), or may materially change the resistance of a defective insulated joint. A loose wedge block may be the source of trouble, or the switch rod, Figs. 19 and 32, may come into contact with the stock rail, making a path of variable resistance. Loose connections such as at binding posts, bonding connections, poorly soldered joints, a break in the wire inside of rubber insulation, etc., are a common cause of this class of failures. Soldered joints, especially of copper to iron wire, may present a good appearance but the joint be poor, owing to the fact that the solder has not made good connection with the iron.

Foreign current is occasionally a factor to be considered, intermittent trouble sometimes being the first indication of its presence in the circuit. Therefore, if other tests fail a foreign current test may prove to be of advantage.

505. When intermittent trouble is present it is desirable to make a very thorough inspection, being careful not to overlook bonding at obscure points such as highway crossings, station platforms, guard rails, detector bars, jumpers under wooden blocking at switches, etc., and bonds behind splice plates.

506. *Clear Failures.* If the armature of a relay on a normally closed track circuit fails to release when the track is occupied, the relay should at once be inspected, first taking the necessary precautions to insure safety. If the relay appears to be in good condition, a voltmeter test at its terminals or a current reading at this point when the track is occupied should if possible, be taken. If a reading below the drop-away point is obtained (the armature being up), it of course indicates a defective relay. If a reading above the drop-away point or only a small percentage below it, is obtained, the trouble is caused either by poor wheel contact or by foreign current.

If it is customary to sand the tracks at any particular point, the effect of a resulting poor wheel contact may frequently be overcome by substituting a relay of higher resistance, and increasing the internal or artificial resistance at the battery (Arts. 147-155).

In a few cases the rust or scale on new rails has been known to cause a poor wheel contact, and it may be necessary in such instances to station a man to watch the operation of the relay until good shunting is insured by the wearing of the rails.

When it is not convenient to get readings with the track occupied, the relay should be tested for its drop-away point.

507. If a relay is found to be defective and a substitute is not immediately available, a tester Fig. 204, or a meter may be connected in place of the relay, if it is desired to ascertain whether or not the circuit is occupied.

508. Normally Open Track Circuits: The most common failures in normally open track circuits, are those resulting from low ballast resistance, the relay failing to release, although the same effect may be produced by crosses in the wiring which may be due to defective wire insulation or other insulation breakdown.

If the relay does not pick up when the track is occupied, it is probably due to a break in the wiring although the relay or battery may be defective. The wiring may be tested by means of test jumpers connected in multiple with them.

509. Records: It is generally required that a record be made of all failures, stating the cause and remedy, and giving such other information as may be of value for comparison with other similar failures. By such a comparison it is apparent that the efficiency of the various types of apparatus and materials employed and the methods of installation, may be ascertained.

EXAMINATION QUESTIONS AND PROBLEMS

(1) Which produces the higher ballast resistance, wet or dry ties?

(2) (*a*) On which side of the rail is it the usual practice to place the bond wires? (*b*) At what points is it desirable to place them on both sides?

(3) Why is it desirable to install bond wires the same day that the holes are drilled?

(4) Give one reason for allowing considerable slack in bond wires.

(5) Why is it undesirable to place bond wires behind splice plates?

(6) If the insulated rail joints separating two adjacent double rail track circuits are staggered sufficiently to allow an engine to stand between them, what effect will an engine thus placed, have upon the circuits?

(7) Why should steel chips be removed when drilling switch rods for insulation?

(8) Why should care be exercised when putting bolts into insulated rail joints?

(9) If in testing an insulated joint, a current reading of 30 mil-amperes and a voltage reading of 1.45 volts is secured, what is the insulation resistance between the parts tested?

(10) Explain the use of a magneto in testing the type of insulated rod, shown in Fig. 20.

(11) State two considerations when locating battery chutes.

(12) Why are the inside corners of turns in trunking rounded?

(13) How is drainage provided in trunking?

(14) Give two methods for fastening capping in position.

(15) Why are slack boxes used?

(16) What is a boot-leg wire?

(17) Why is it desirable to test pipe line insulations before installing them?

(18) Would it be good practice to install a ground plate in dry sand?

(19) (*a*) At what points in a track circuit installation are flexible wires generally used? (*b*) For what purpose are they employed?

(20) Why are wires tagged?

(21) State what procedure you would follow when setting up a gravity battery for immediate use on track circuits.

(22) From charts Figs. 199-201: (*a*) What was the current output from the battery on the 38th day, with the track unoccupied? (*b*) What was the current through the relay at the same time? (*c*) Where was the line of demarcation on the 42nd day? (*d*) What was the voltage across the track on the 28th day?

(23) If current readings of 160 and 350 mil-amperes are taken at the relay and the battery respectively, of a normally closed track circuit using a 5-ohm relay, what is the ballast resistance?

(24) Of what value are track battery records?

(25) After working on a battery, what method is employed to insure that the battery and connections are in good condition?

(26) What size storage cell is commonly used on track circuit work?

(27) Are storage batteries for track circuit purposes generally connected in series or in multiple when being charged?

(28) When testing with an instrument on the track, what method is used to secure good rail contact?

(29) What is the ballast resistance on a length of track, if the mil-ammeter gives a reading of 110 mil-amperes, and the voltmeter a reading of 1.2 volts?

(30) Explain a ballast resistance test which uses only a mil-ammeter.

(31) When making a current test of a storage battery: (*a*) Should the mil-ammeter be connected across the battery terminals, or should the artificial resistance be placed in series with them? (*b*) Why?

(32) If a noticeable voltage is obtained when one terminal of the meter is connected to a bond wire and the other to the rail to which the bond is attached, what does it indicate?

(33) Why is it often difficult to locate defective bonding?

(34) If across the rails of a multiple fouling section a reading of .65 volt is secured and across the rails of the track to which the section is connected, a reading of 1.2 volts, what condition is indicated?

(35) Describe a test for indicating the presence of foreign current.

(36) Why is trouble due to foreign current not always indicated by a test?

(37) Explain the manner in which transpositions assist in overcoming foreign current trouble.

(38) If the relay of a normally closed track circuit remains picked up when the track is occupied the voltage at its terminals being well below its drop-away point; does it indicate trouble in the circuit or in the relay?

(39) On what type of track circuit is it necessary to exercise particular care not to reverse the connections of the battery?

(40) What is indicated by a high voltage across the rails near the battery and a low voltage near the relay, on a normally closed track circuit?

(41) If the ballast resistance of a normally open track circuit using a 4-ohm relay drops to 6 ohms, the battery giving .75 volt, what will be the result?

(42) If there appears to be high resistance in a pole changer contact, explain the test which should be applied.

(43) If a higher voltage is obtained across the rails, at the relay end of a normally closed track circuit, than is found near the battery, what condition is indicated?

(44) If the resistance between two parts of an insulated rail joint is 45 ohms and the voltage used in testing is 3 volts, what current reading should be obtained between these parts?

(45) Why should a boot-leg connection have considerable mechanical strength?

ANSWERS TO EXAMINATION PROBLEMS

(1) to (8) ?

(9) 48.3 ohms.

(10) to (22) ?

(23) 4.2 ohms.

(24) to (28) ?

(29) 10.9 ohms.

(30) to (43) ?

(44) 66.7 mil-amperes.

(45) ?

HIGHWAY CROSSING SIGNALS

1. At highway grade crossings it is the general practice to provide means to *warn* those using the highway of the approach of trains.*

In some cases it is required that trains reduce speed when approaching such crossings, but, as a rule, when warnings are provided, this is considered unnecessary.

2. Methods of Warning: A *sign post* bearing a suitable inscription, such as "RAILROAD CROSSING DANGER", is generally erected at all highway crossings, and in many cases a post suitably marked, such as with the letter W, known as a *whistle post,* is located a certain distance from the crossing, the engineman being required to whistle when passing it, while approaching the crossing. The locomotive bell is also rung while the train is passing from the whistle post to the crossing. The whistle post is especially desirable where no other means are provided to give warning of the approach of trains.

3. It is customary also to station *flagmen* at the crossings, whose duty it is to warn those using the crossing, of the approach of trains.

Where there are two or more tracks, and in some cases on single track roads, *crossing gates*** are employed, as they are more effective than flagging.

To assist the flagman† an annunciator, is sometimes provided, being operated by the trains when they approach within a cer-

*In some instances means of warning are provided at points where the highway passes under the tracks, in order that horses which are easily frightened, may not be under the tracks during the passage of a train.

**These gates upon the approach of trains, are moved by the flagman to a position spanning the highway on each side of the tracks.

†This term as here used is understood to mean persons flagging, or operating crossing gates.

tain distance from the crossing. In some cases the annunciator is arranged to give a visual as well as an audible indication.

4. Some railroads require that their enginemen receive a signal from the flagman before proceeding over the crossing. This same result is accomplished in a few instances by locating fixed signals, a short distance from the crossing, and so controlling them, that they cannot be cleared for the passage of a train until the crossing gates are in a position to prevent access to the tracks.

At some points the crossing gates are arranged to swing across the tracks when the highway is being used. Therefore, if the gates do not span the tracks, it indicates to the engineman that he may proceed, the highway being closed.

5. At many crossings, it is not thought desirable to incur the expense required to provide the services of a flagman, on account of the infrequency of train movements, and the small amount of traffic on the highway. In some instances such conditions prevail only at night, at which time the attendant is dispensed with. To provide adequate warning in such cases, it has been found advantageous to install automatic alarms, which give an indication when the trains are a certain distance (from 1,000 to 3,000 ft.) from the crossing, this indication continuing until the trains reach the crossing. The distance is of course, governed by the maximum speed of the trains.

6. Alarms usually consist of large electric bells, in some cases electric lamps being used in connection with them. These lamps are so placed, that a *danger* indication is given on the highway and with certain types, a *clear* indication on the track, being arranged to give an intermittent, or a continuous light, *only* when the trains are approaching. Thus where bells and lamps are employed, people using the highway are given an audible indication in the day time and at night both an audible and a visual indication. The type of lamp which emits light both on the highway and track, also indicates to the engineman, whether or not the alarm is operating properly.

It is customary to have the alarms tested daily, frequently by the track patrolman. If an alarm is found to be out of

order, a temporary flagman is stationed at the crossing until it is repaired.

7. As an additional precaution, it has sometimes been found desirable to install alarms, at points where flagmen are stationed and also at points where crossing gates are used.

8. **Methods of Operating Alarms**: Alarms are controlled through *relays* operated by *track circuits, track instruments, trolley switches* or *contacts,* and also by *time circuit controllers.*

9. *Track circuits.* In many cases the alarms are controlled by *ordinary neutral track relays* suitably interconnected, while in other instances, the desired results are obtained by *interlocking relays,* which form part of the track or line circuits.

Short track circuits, so located as to start and stop the operation of the alarm at the proper time, are sometimes employed to provide means of control, the control circuits being carried through line wires.

10. *Track instruments.* These devices are operated by a train passing over them, a part of the instrument being deflected by actual contact with the wheels or by the deflection of the rails. They are so arranged that when operated, a circuit controlled by them is opened or closed, producing the same results as obtained with the short track circuits.

Track instruments are employed where it is not desired to install track circuits, as for instance where the rails are employed as a return for propulsion current, and in some cases where the track circuits are used to control apparatus foreign to the crossing alarms, at which points it is considered undesirable, on account of the complications which would arise, to control the crossing alarm through track circuits.

11. *Trolley switches or contacts.* These devices are operated by the trolley wheels or trolley poles, and are so arranged that their effect is similar to that obtained by the use of the short track circuits or track instruments.

12. *Time circuit controllers.* These mechanisms are controlled by means of short track circuits or track instruments. located at a suitable distance from the crossing. They are so constructed that when operated they will keep the bell ringing for a predetermined length of time, this being governed by the time required for trains traveling at an ordinary speed to reach the crossing.

This arrangement is used to advantage where trains are required to stop after they have started the bell ringing, but before they reach the crossing, such as at stations, for switching purposes, etc., as the bell will stop ringing at the end of the given time. Of course, no alarm would be given when the train again starts toward the crossing, but in such cases, it is considered unnecessary as the train is then usually moving slowly.

13. The *flagman's annunciator* is operated by track circuits or by track instruments located at a suitable distance from the crossing, the controlling circuits being carried by line wires. when necessary.

MATERIALS OF CONSTRUCTION

BELLS

14. The bells employed for automatic alarms' are usually of the vibrating type. They vary in size from 8 to 20 in. in diameter, 12 in. gongs being most commonly used.

The bells used for annunciators for flagmen, vary in size from 2½ to 8 in. in diameter.

15. A very common type of vibrating bell, known as the **skeleton frame bell,** is illustrated in Fig. 1.*

In some cases back straps for the magnet cores, are provided.

*See **Magnetism and Electricity** for the principle of operation.

but the cores are frequently attached directly to a *back yoke* A, cast as a part of the iron base, as shown in Fig. 1.

The cores are usually provided with brass or copper armature stops. The magnet coils are generally *core wound,* the ends being protected by hard rubber or vulcanized fiber magnet heads, and the sides with book binders cloth or heavy linen cord treated with waterproof compound. It is considered good practice to impregnate the coils.

Fig. 1

16. The armature is pivoted on a steel rod, provided with *cone shaped* or *cylindrical* trunnions. The arrangement of the armature hanger B* for the bell shown in Fig. 1, is illustrated in Fig. 2. It will be observed that the frame 1, is attached to the base 2, by means of two screws 3, the *lower* trunnion bearing 4 acting as a dowel. The holes in the base and in the hanger are sometimes made in the form of slots, so as to allow a slight lateral adjustment of the armature.

The *upper* trunnion bearing 5, is adjustable, being so arranged in order to take up the wear of the trunnions and bearings. It is held in place with a check nut as shown, or other locking device. When cylindrical trunnions are used the upper trunnion bearing is often made in the form of a cap screw, non-adjustable, the lower bearing being simply a hole drilled in the frame.

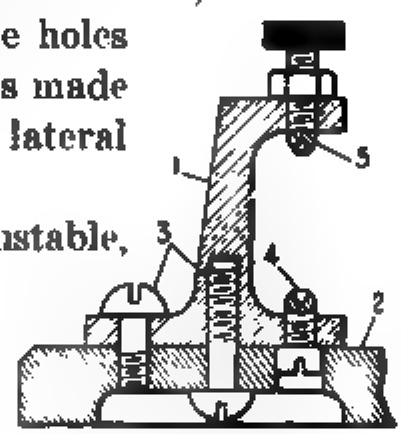


Fig. 2

17. The *hammer*** and its rod C, is securely fastened to the free end of the armature.

The *tension spring* D, is made of a metal, such as phosphor bronze, brass, or of steel piano wire. The tension of the spring

*Also called *trunnion frame.*
**Also called *clapper*, or *tapper*.

shown in Fig. 1, can be changed by the adjusting rod E, to which the spring is attached, and which passes through the tension post F. This rod is threaded at one end, being adjusted by thumb screw G and locked by screw H.

The tension spring strap J, which forms the connection between the spring and the armature, is either screwed or riveted to the latter.

18. The contact spring K, which is also secured to the armature, sometimes being held beneath the tension spring strap, is made of brass or phosphor bronze, preferably the latter. *Platinum contacts* are generally provided these being riveted into the ends of the spring. In order to secure the same flexibility and at the same time employ heavier material, contact springs are sometimes formed as shown in Fig. 3.

Fig. 3

19. An enlarged detail of the contact post L, is shown in Fig. 4. The contact screw 6, which is adjustable, being locked in position by screw 7, has a platinum tip. The two screws 8, which secure the post to the base 9, and prevent it from twisting, are insulated from the base by means of hard rubber or vulcanized fibre plates, or washers and bushings.

20. An arrangement of the contact spring and post somewhat different to that described,

Fig. 4

in Fig. 5. As will be seen the spring l into three fingers each being provided ntact point. The contact screw is made with a T-shaped end carrying three tips, one for each finger, and is locked in position by the lock screw.

21. Another method of arranging the contacts shown in Fig. 5, is illustrated in Fig. 6. In this case an additional spring 12, is

Fig. 5

substituted for the T-head, contact points being attached to this spring in the same manner as to the fingers. An ordinary set screw 10, locked in place by screw 11, is employed to secure the proper adjustment.

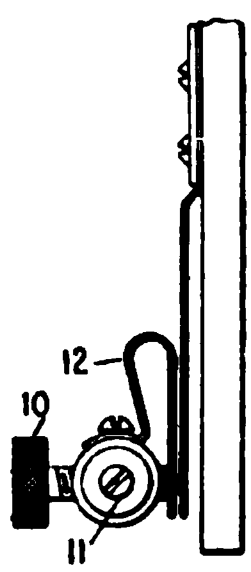


Fig. 6

Binding post M, Fig. 1, is secured to and insulated from the base, in the same manner as the contact post. Binding post N, however, in the bell shown, is cast as a part of the base.

22. The electrical connections are as follows: From binding post M, through the upper coil, lower coil, contact post L, contact spring K, to the armature and its hammer which are grounded to the base, current passing through the base to binding post N. Current may also pass from the armature through the tension spring to the base.

The path through the armature hanger bearings is liable to develop resistance on account of corrosion or the presence of oil, and to avoid trouble from this source a spiral jumper made of a fine wire or small stranded wire is sometimes used, being connected from the contact spring in multiple with the path through the frame. The wire is very flexible so as not to impede the action of the armature,

In some instances, especially with the larger bells, the base is not used as a path for current, although the circuit is not insulated from it, while in other cases the circuit is entirely insulated.

23. Gong P, Fig. 1, is made of bell metal, or of cast or pressed steel, the hole sometimes being drilled slightly *off center* so that by turning the gong, a different adjustment may be obtained. In other cases means are provided to prevent the gong from turning and thus accidently getting out of adjustment.

24. Metal parts which are liable to rust, are generally nickel plated, or otherwise suitably finished.

25. An **enclosed type** of the bell shown in Fig. 1, is illustrated in Fig. 7. It will be noted that a gasket (rubber

or felt) is provided upon which the cover fits, making a weather-proof joint.

26. Another form of the enclosed type, with the cover in place and locked, is shown in Fig. 8. The wires are brought into the case through loricated iron conduit, thus being protected. The cover over the gong protects it and also the hammer from the interference to which crossing bells are especially subject.

Fig. 7

27. The small types of bells are wound as low as 1.4 ohms, the resistance usually increasing with the size of the gong. The following table gives the resistances of bells of different sizes and the voltages required to operate them, these values being employed by a prominent manufacturer.

Fig. 8

Gong Inches	Ohms	Volts	Gong Inches	Ohms	Volts
2½	1.4—1.5	2.5	8	3	5
3	1.4—1.5	2.5	9	5.2	7
3½	1.4—1.5	2.5	10	5.2	7.5
4	1.4—1.5	2.5	12	5.2	8
5	2.1	3.25	14	5.2	8
6	2.1	3.25	15	5.2	8.5
7	3	5	18	8	11

Of course, it is sometimes desirable to alter these resistances to suit local conditions, such as available voltage, etc. For instance, if current from a higher voltage battery employed for other purposes, is available, it would probably be more economical to have the bell wound to a higher resistance, thus adapting it to the higher voltage, than it would be to use only part of the battery on the bell circuit, causing the cells used in this manner to exhaust more rapidly than the balance of the battery.

28. Devices known as **buzzers** (constructed like a small bell with the gong and hammer omitted) are sometimes employed instead of small bells.

29. Another type of bell, the operation of which is similar to that just described, is illustrated in Fig. 9, and an enlarged view of the operating parts in Fig. 10.

Fig. 9

As will be seen a *flat* tension spring is employed, being secured to the armature hanger engaging with the armature thrc of the *link* or *stirrup*.* The ten called the *front* contact spring contact points. The other, known as the *back* contact spring is held by screws, in an adjustable stud, the adjustment being obtained by loosening the screw in the slot and moving the lever either to the right or left as required.

Instead of depending upon the core pins to act as a stop for the armature, an adjustable stop-yoke is sometimes provided, this device being attached to the base in such a manner that it will receive the blow of the free end of the armature.

*Also called *spring holder*.

It will be observed that the motion between the contact springs is such that the contact surfaces *slide* on each other, thus tending to keep them clean.

30. There are three kinds of contacts used with this bell: First, *platinum,* the front contact spring having three platinum plates attached to it, and the back contact spring being divided into three fingers each fitted with platinum: Second, *carbon,* each spring being fitted with a carbon block: Third, *silver carbon,* in which the carbon blocks are silver plated.

31. The movement of this type of bell, is frequently mounted upon an *enameled slate base,* thus insuring good insulation of all parts, although *wood* and *iron* bases are often employed.

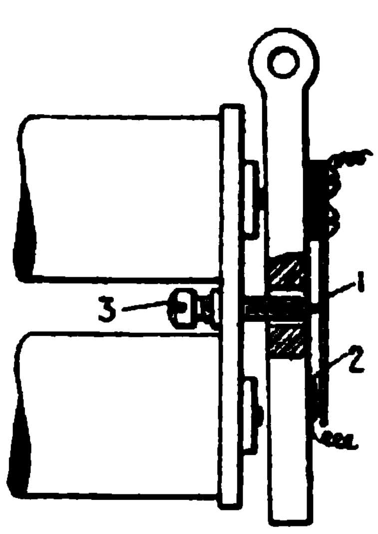


Fig. 11

32. Another method of arranging contact springs is shown in Fig. 11. The circuit is completed through spring 1, and contact 2, this path being broken when the armature is attracted to the coils, by the insulated adjusting screw 3, which passes through the armature, and forces spring 1, away from contact 2, at the *end* of the forward stroke.

33. Another type of vibrating bell is illustrated in Fig. 12. The operating parts are mounted so that the hammer 1, which

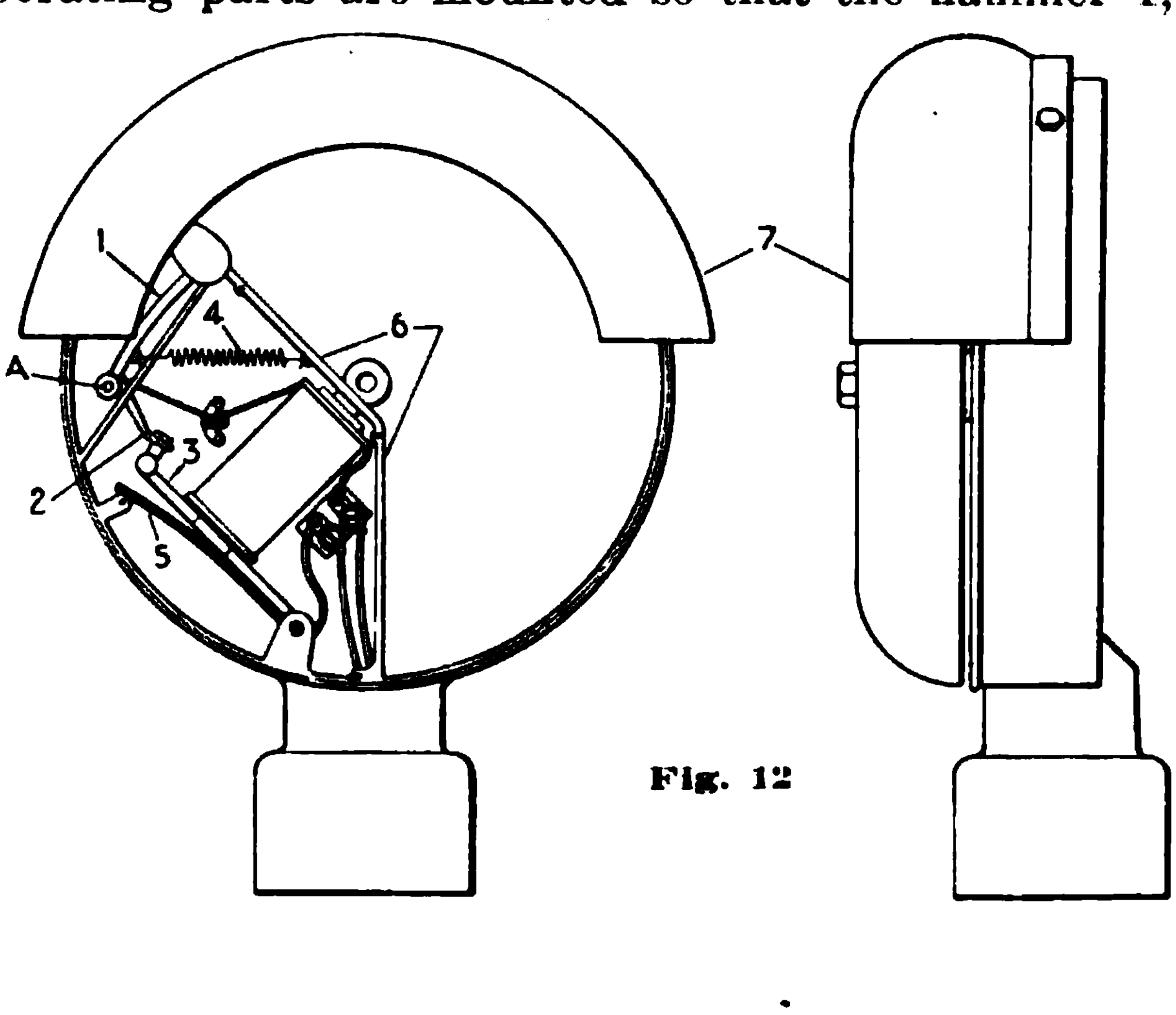


Fig. 12

is *inside* the bell, will fall away from it when the circuit is broken. The hammer is rigidly attached to its operating arm 2, which is pivoted at point A, the free end of the operating arm resting upon that of the armature bar 3, and thus forming a contact through which the bell circuit is controlled. When the operating circuit is closed the armature is drawn up against its stops, thus raising the hammer which continues in motion, after the armature has stopped, until it strikes the bell. The circuit is broken when the operating arm leaves the armature bar, and consequently the magnet is de-energized, the armature being forced away from the coils by a flat spring riveted to it, placed *between* its face and the pole faces. The hammer rebounds from the bell, assisted by spring 4, and the operating arm again comes into contact with the armature bar, forcing it further from the magnet, bending spring 5, and again completing the circuit. This spring then unites with the magnet in returning the armature and throwing the hammer against the bell.

34. From the foregoing it is apparent that, as the circuit is not broken until the armature strikes its stops, the magnet can exert its attractive force at the time when it will be most effective in delivering a strong blow on the gong.

35. Spring 5, is usually composed of *two* flat springs laid together and riveted to the armature bar near its pivot.

The contacts are insulated from the operating arm and armature bar, the controlling wires being carried to the contacts:* Thus, all parts carrying current are insulated from the base. A sliding motion between the contacts tends to keep them clean.

36. The entire mechanism except the hammer is protected by an iron cover (not shown) which is attached to the ribs 6, this being employed to keep out any foreign matter such as insects, etc., which might interfere with the operation of the bell. The *cover* or *hood* 7, acts as a protection against the weather.

*The wire to the contact on the armature bar does not show clearly in the illustration, as it is first carried to the pivoted end of the armature and then beneath it to the contact.

37. Two sizes of one type of **double bell**, are illustrated in Fig. 13, a diagram of the wiring connections and operating parts, being shown in Fig. 14. As may be seen *two* independent single coil magnets* are used, *one* piece of iron pivoted in the center acting as an armature for both magnets.

Fig. 13

The hammer is rigidly secured to the center of the armature, the movement of the latter transmitting a corresponding movement to the hammer, thus causing it to strike one of the gongs in either position.

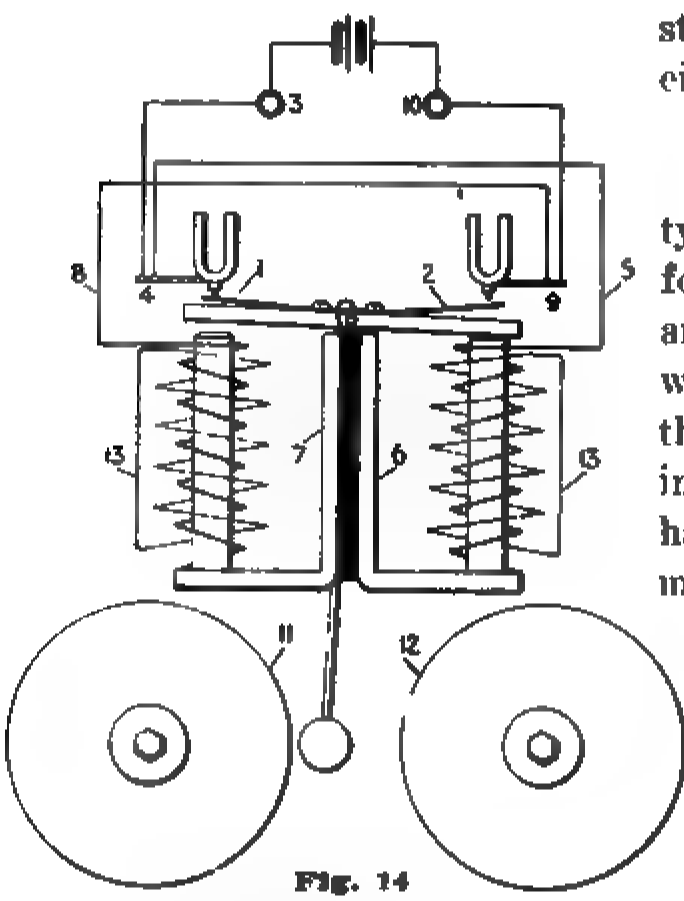


Fig. 14

38. The operation of this type of bell is explained as follows: If both contacts 1 and 2, are open, the current would flow from the battery, through binding post 3, terminal 4, wire 5, and the right hand coil to leg 6, of this magnet; from thence it would flow through leg 7, and the coil of the other magnet, to wire 8, terminal 9, binding post 10, and to the battery. As, in such a case, the same current would flow through both coils, they would exert an equal attracting force, thus tending to hold the armature and hammer in a central position. As this is not what is desired, contacts 1 and 2 are so adjusted that when the controlling circuit is broken,**

*See **Magnetism and Electricity**, *Electro-magnetism*.

**Although in the illustration, the controlling circuit is carried without a break to the bell, it is of course, controlled by relays or other suitable devices.

and the hammer hangs by gravity in the center, one of these contacts, for instance 2, is closed. In such a case, it is evident that the left hand coil would be shunted, by the path through this contact, thus allowing the right hand coil to attract the armature to the position shown and consequently causing the hammer to strike gong 11. Contact 2, would now be broken and contact 1, made as shown, thus shunting the right hand coil, allowing the left hand coil to attract the armature therefore causing the hammer to strike gong 12, and again closing contact 2.

39. It will be observed that each coil is provided with a *closed secondary winding* 13. These windings act inductively upon the cores retarding the loss of magnetism when each coil is shunted, thus assisting in completing the stroke of the hammer. They also tend to reduce the sparking at the contact points.

40. As the controlling circuit is not opened by the operation of the bell, two or more can be connected in series if desired, without their interfering with one another. However in some types of double gongs the circuit is broken instead of being shunted out of the coils.

Reference to the illustration will show that the hammer of the larger gong is protected by a shield from mechanical injury.

41. Another method of arranging and protecting a double gong is illustrated in Fig. 15. This also shows a means employed for adjusting the gong.

LAMPS

42. The **lamps** which are used for giving a visual indication at highway crossings are usually ordinary incandescent lamps of about 6 C. P., arranged to light on the voltage used for the bell. A type of lamp used for this purpose and the casing for same, is shown in Fig. 16.

Fig

Another method sometimes employed is to mount the lamps in weather-proof marine sockets.

BELL POSTS AND SIGNS

43. A very common type of **bell post*** is shown in Fig. 17. This post is made of wood (generally yellow pine) and is 12 to 18 ft. long, being set from 3½ to 5 ft. into the ground. The *bell* is mounted from 8 to 12 ft. above the ground, thus placing it where it is not likely to be interfered with.

In this case a *relay box* is attached to the post at a convenient height, and an *iron battery box* is located at the foot of the post.

The wires are carried up the post in trunking or in a groove cut in the post.**

If a lamp is used, it is usually mounted on top of the post, which is arranged to receive it.

In some cases, where battery chutes are used, the bell posts are supported by them, in a manner similar to that employed for supporting relay posts.

Fig. 17

44. At locations where the nature of the earth requires, the

*Sometimes called *tower*
See **D. C. Track Circuits, *Relay Shelters.*

bottom of the post is provided with bracing, as shown in Fig. 18. This arrangement is often termed a *spider*.

45. Other forms of bell posts are shown in Figs. 19-21. It will be noted that they are built of iron pipe and are provided with a *sign* bearing a suitable inscription. In some instances the bells are mounted on these posts. The *letters* on the signs are usually raised so that they may readily be painted.

Fig. 19 Fig. 20 Fig. 21

As shown in Fig. 19, an opening is provided in the iron base, to receive the trunking, the wires being carried up the inside of the post and through openings to the relay box and bell.

46. Another type of bell post, which is constructed of an I-beam and angle iron, is illustrated in Fig. 22.

The trunking, in this case, is fitted into one of the channels of the I-beam, as shown in the sectional detail, being screwed or bolted in position.

BELL AND RELAY SHELTERS

47. As will be observed, the construction of several of the bells shown, provides sufficient protection against the weather and also against interference, but where *skeleton frame bells* or other *unprotected* types are to be installed, such protection must be provided.

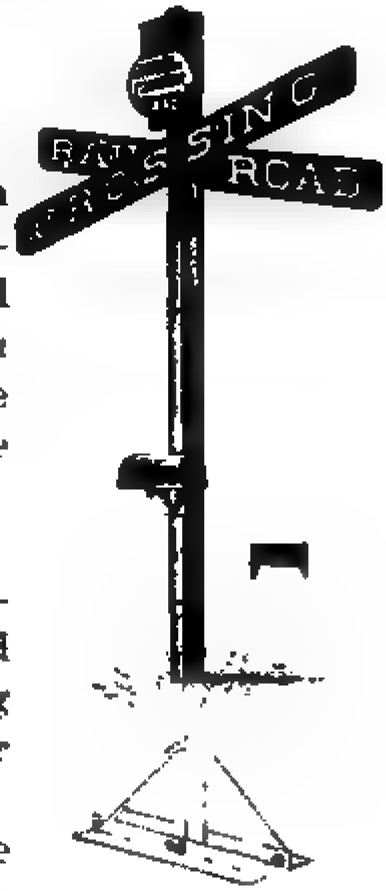


Fig. 22

48. A *wooden box* employed for this purpose, is illustrated in Fig. 23. It is arranged to set on top of the bell post, a casting being fitted into the base of the box for this purpose.

Heavy wire screening is provided in the sides and door as shown, in order that the bell may be protected from mechanical injury,* without interrupting the sound. The spark-arrester screen used in locomotives is often employed to good advantage, as it is very strong, and has a fairly large mesh, which is not likely to allow snow to collect in the box.

Fig. 23

49. Another type of wooden box, built to contain the bell, relay and lightning arresters, is illustrated in Fig 24 It is arranged to be screwed or bolted to the side of the bell post.

Fig. 24

*They are often made a target for stones, etc.

50. In many cases, boxes of this type are built without the relay compartment, while in other cases, the box only acts as a cover for the bell mechanisms, the gong and hammer being exposed. Cast iron shelters with wooden linings are also made to contain bells.

51. The material and general methods of construction employed in making wooden relay boxes* are adaptable for bell boxes.

52. Relay boxes* of the ordinary types are frequently used in crossing alarm installations. A type of box sometimes used in this class of work is shown in Fig. 25. It is also made to contain but one relay, as shown in Figs. 19, 21 and 22.

When battery houses** are provided it is customary to shelter the relays in them.

Fig. 25

TRACK INSTRUMENTS†

53. The device illustrated in Fig. 26, is known as the **Hall track instrument.**‡ This illustration shows a section through the center of the instrument and an enlarged detail of the smaller operating parts.

As indicated the instrument is bolted to a long tie (usually 8″ x 12″ x 11′-0″), the bolts being kept from turning by pieces of channel iron which engage their heads beneath the tie as shown.

54. The steel lever 1, is pivoted on the steel fulcrum pin 2, in the chair 3, and is held between two *rubber springs* 4. In some cases the steel lever has a hard steel piece bolted to

*See **D. C. Track Circuits.**
**See Art. 90
†Also called *trips*
‡Also called *nigger heads*

the end nearest the rail, this piece being renewed when worn. The springs are compressed by screwing down the *adjustable yoke* 5, thus preventing the lever from moving unless considerable force is exerted upon it, such as that caused by a car wheel striking the lever at its free end.

18

Fig. 26

When the tread of the wheel strikes the lever, which stands about $\frac{1}{8}$ in. above the top of the rail, the other end throws *spindle* 6, upward. The *swinging arm* 7, which is pivoted on pin 8, is provided with a *roller* 9, so arranged that the tapered portion of the spindle at its upper end, engages with the roller and forces the swinging arm towards the block 10. The swinging arm carries an upright pin 11, fitted with an *insulating bushing* 12, which is protected by a *brass shield.* The bushing presses *contact spring* 13, against *contact plate* 14, thus closing the circuit from binding post 15 to 16. The contact spring and plate are furnished with platinum contacting faces.

When the spindle drops, the contact spring forces the swinging arm back and again opens the circuit; it is assisted in doing this by a helical spring 17, placed between the spring and the block. The contact spring is guided by the wire *guard* 18.

From the foregoing it will be seen that the circuit is closed momentarily as each wheel passes over the lever.

55. If it is desired to control a *normally closed* circuit by this instrument, the contact plate 14, is arranged to extend *over* contact spring 13, as shown at A, Fig. 27, the spring resting against the plate, except when pushed away by the swinging arm.

Fig. 27

56. In cases where it is desired to control another circuit, two bushings are placed on pin 11, and a second contact spring and plate are mounted on the lower side of the block, as shown at B, Fig. 27, the block being arranged so that the spring will not touch the *top plate* 19.

57. The piston, Fig. 26, which is made as a part of the spindle 6, moves in cylinder C, being provided to check the upward movement of the spindle. As the piston starts to rise, it forces the air above it through port D, valve E and passage F, to the underside of the piston. Thus by adjusting valve E the flow of air may be regulated to properly retard the motion of the piston. When the piston covers port D, it confines the air above the piston, which forms a cushion and absorbs the shock of the blow.

58. The valve stem 22, which extends through the top plate, being screwed into it, is held in place by the wire *valve spring* 23, one end of which fits into a hole in the top plate. To adjust the valve, the spring is raised out of the hole in the plate and the valve turned until the desired adjustment is obtained, the end of the spring again being placed in one of the holes, which secures the valve in position.

59. The *bonnet* 24, protects the contacts, etc., from the weather. The wires are usually brought into the instrument through a piece of iron pipe.

The *dust guard* 20 and its spring 21, move with lever 1.

60. The **O'Neil track instrument,*** is illustrated in Fig. 28.

*Also called the *O'Neil track box.*

This instrument is generally arranged to be supported by the ties, although in some instances concrete foundations are

Fig. 28

used As indicated, it is operated by the deflection of the rail. due to passing trains.

61. A *rubber bumper* 1, is attached to the lever 2, to absorb the shock if the lever strikes the cover when raised by the deflection of the rail. A retractile spring 3, also assists in this regard.

62. A contact spring 4, is mounted upon an *adjustable* hard rubber block 5, which insulates the spring from the case. A brass contact piece 6, is mounted upon a block of hard rubber attached to the end of the lever, thus being insulated from it.

The wires of the controlled circuit are attached to the binding screws 7 and 8. It is therefore apparent that when the lever is operated, contact piece 6, will be forced in contact with spring 4, consequently completing the path between the binding posts.

The position of the spring shown by solid lines is used for normally open circuits, and that shown by dotted lines, for normally closed circuits.

TIME CIRCUIT CONTROLLERS

63. Two views of a common type of automatic time circuit controller, known as a **time circuit breaker,** are shown in Fig. 29. The armature of this device vibrates, due to carrying the circuit for its magnet through a back contact, in a manner similar to that employed in the ordinary vibrating bell.

64. The operating circuit, which is connected to binding posts 1, 2 and 3, is shown more clearly in the diagram, Fig. 30, which for convenience shows the instrument arranged to be started by a key A. It will be observed that contacts 4 and 5 are normally open, and, being in multiple, if either is closed, the armature will vibrate; also if the key is closed the armature will vibrate regardless of the position of these contacts.

Fig. 29

Fig. 29

Flat brass strips 10 and 11, are used for connection between the binding and contact posts.

65. The armature, when vibrating, raises and lowers the connecting rod 12, thus operating the angular casting 13, which being pivoted in the frame 14, at point B, moves the *driving pawl* 15, laterally. This pawl engages with the *ratchet wheel* 16, moving it one notch at a time, the *stationary pawl* 17, being employed to prevent the ratchet wheel from turning backward. Both pawls are provided with springs to insure their quick operation.

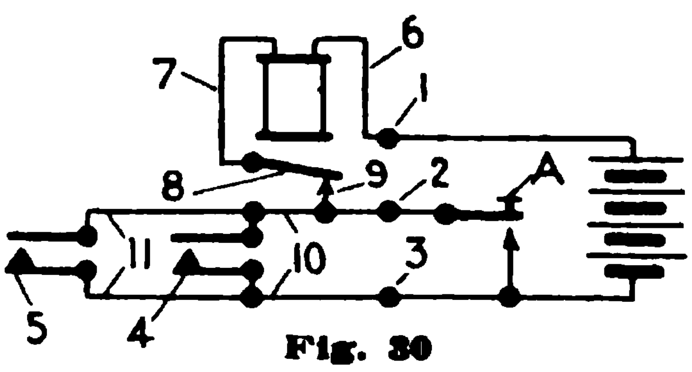


Fig. 30

The *adjustable weight* 18, which is supported on casting 13, by a strip of spring steel, acts as a counterweight, and insures the full stroke of the armature.

66. The ratchet wheel 16, carries a lug 19, which normally engages with *trigger* 20 as shown, to hold contact 4, open. It also revolves a small *pinion* (not shown) which drives *gear wheel* 21, at a ratio of 6 to 1. This gear carries a stud 22, which normally engages spring 23, thus holding contact 5 open.

67. Mounted on the same shaft with gear 21, and moving with it, is an arm 24, which operates contacts on springs 25, 26 and 27, by pressing against the ivory block on the upper end of spring 26. These contact springs are suitably connected to binding posts 28, to which the circuits *controlled* by this instrument are attached.

When the instrument is in its normal position, spring 26 is forced against spring 25, but after arm 24, starts to revolve, it clears the ivory block, allowing spring 26 to draw away from spring 25 and make contact with spring 27.

68. If when the instrument is in its normal position as shown, key A should be closed, the armature at once begins to vibrate, revolving wheel 16 and moving lug 19, out of engagement with trigger 20, thus allowing contact 4 to close. Key A may now be released as the circuit for the magnet is completed through contact 4, the armature therefore continuing to vibrate. When wheel 16 has made a complete revolution, lug

19 again breaks contact 4, but in this instance, the circuit through the coils is *not* broken, as gear wheel 21, has revolved sufficiently to move stud 22, out of engagement with spring 23, thus closing contact 5 and consequently maintaining the circuit through the magnet and causing the armature to continue to vibrate until gear 21 has made a complete revolution, thus again bringing stud 22, into engagement with spring 23, to open contact 5. As contact 5 breaks, lug 19 engages with trigger 20 to break contact 4; thus both contacts being broken at the same time, the circuit for the magnet is opened and the armature therefore ceases to vibrate.

69. It is apparent that as a complete operation of the instrument requires *one* revolution of gear wheel 21, and therefore *one* revolution of arm 24, contact springs 25, 26 and 27 will be reversed directly after it commences to operate and again restored to their normal position when it ceases to operate.

70. This instrument is usually so adjusted that it will require three minutes for the gear wheel to revolve. If it is desired that the instrument be stopped in a shorter period of time, additional studs 22, are placed in holes provided for that purpose in the gear wheel and additional arms 24, in the hub. For instance, to set it for 1½ min., one additional stud would be set in the gear wheel *opposite* stud 22, and another arm in the hub *opposite* arm 24; thus the instrument will have *two* positions in which it will remain at rest. To set for 1 min., three studs and arms, set at angles of 120 deg. to one another, would be employed, etc.

71. In some instances, it is desired to employ a *normally open* contact, which is closed by arm 24 while passing it, during the operation of the instrument, This is accomplished by setting the arm so that, in its normal position, it will not engage with the block (Fig. 31, sketch B).

72. Space is provided for two additional sets of contacts, similar to 25, 26 and 27, each set being operated by one or more arms mounted on separate hubs.

The coils are usually wound to a resistance of 8 ohms, and adjusted to operate on a potential of from 2 to 3 volts, although of course, these values may be varied to suit the circuit on which the instrument is to be used.

73. The symbol ordinarily used for this instrument is shown in Fig. 31, the reference numbers corresponding with those given in Figs. 16-17. Sketch A, shows the symbol used when the arms rest against the ivory blocks, in their normal position, and sketch B, when one of the arms is normally above the block (Art. 71).

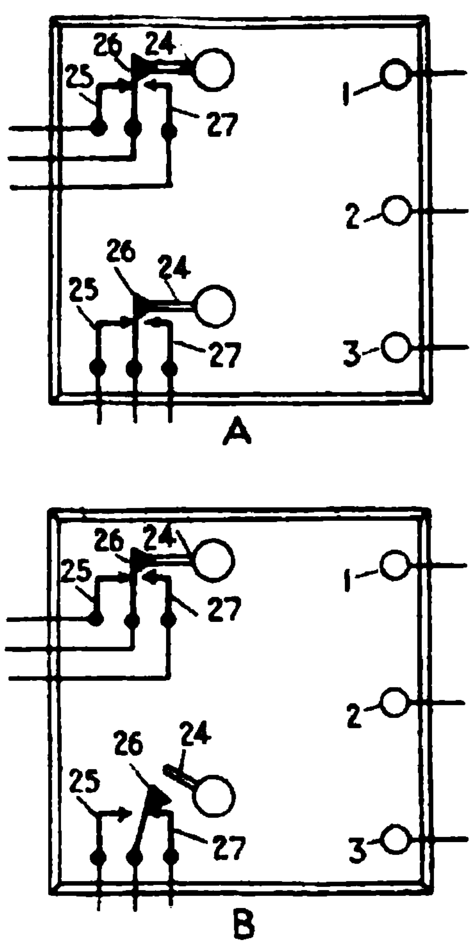


Fig. 31

74. Other types of time circuit controllers, used in connection with crossing alarms, known as **escapement relays** and **registers**, are clockwork mechanisms operated by *weights* or *springs*, which are wound periodically. The weight or spring is released by the armature of an electro-magnet, the clockwork running for a predetermined length of time, being stopped in a position to be again started by the next operation of the armature. One type of this class of instrument, known as the **R. & H. escapement relay** is illustrated in Fig. 32.

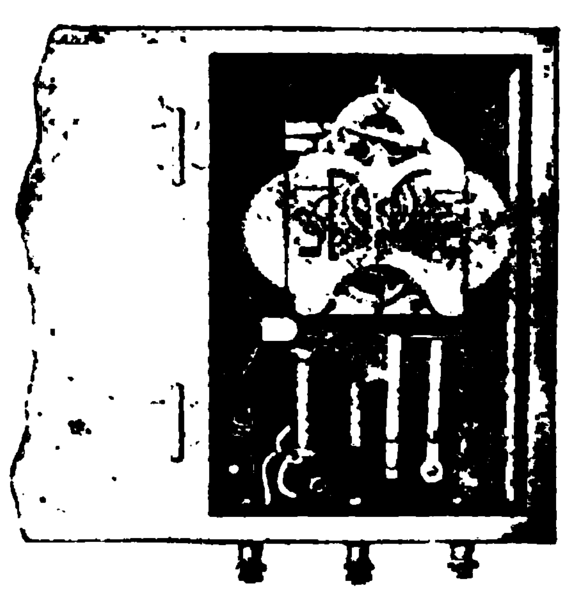


Fig. 32

75. Another arrangement for operating a bell for a certain length of time, is to connect a pawl to the armature of the bell in such a way that it will turn a ratchet wheel and control contacts on the same principle as the time circuit breaker, Fig. 29. This is known as a **time bell**.

Aside from the regular bell magnet this instrument has another electro-magnet whose armature closes the bell circuit and starts the mechanism. While the mechanism is revolving

this armature is held mechanically against its magnet, thus keeping the bell circuit closed; however, when the movement is complete the armature is allowed to assume its normal position ready to start the mechanism when its magnet is again energized.

76. Another device, known as a **time element,** for operating an alarm for a given length of time, is illustrated in Fig. 33. This mechanism is started by momentarily closing a circuit through the coils of the *mercury relay,* which in turn completes the circuit for the *solenoid relay,* closing its contacts and completing the alarm circuit. The solenoid relay employs a *stick circuit,** thus remaining energized, after the mercury relay is de-energized.

When the mercury relay is momentarily energized its armature, in addition to closing the solenoid relay circuit, operates a ratchet device which controls two of the contact rings. The motor which is connected in series with the bell** circuit, is employed to restore the ratchet device to its normal position, and for this purpose is fitted with worm gears which reduces its speed in the ratio of 1,700 to 1, consequently requiring a certain length of time to restore this device. When the contacts operated by the ratchet device are restored to their normal position, they *shunt* the coil of the solenoid relay, thus opening the circuit through the motor and bell.

The motor is arranged with a special winding designed to give a high starting torque, in order to avoid the possibility of the motor sticking.

*See Arts. 142-143.
**The bell is of a type that does not open its circuit, as in Fig. 14

This instrument may be adjusted to operate for any length of time between 20 sec. and 2 min.

HIGH VOLTAGE APPARATUS

77. On electric railways where the cars are propelled by direct current, it is very convenient to use energy from the trolley wire, third rail, or feeder, to operate signal apparatus.

78. As the potential employed is usually at least 500 volts, it is desirable to reduce it to a point where it can be handled without danger of severe shock. This is generally done by inserting resistance in series with the apparatus to be operated.

79. An ordinary coil of insulated wire could be used to obtain the required resistance, but in case of an excessive flow of current, which would heat the coil, the insulation is liable to become charred or carbonized, forming a short circuit between the turns of wire, thus reducing the resistance of the coil and producing a higher voltage at the terminals of the instrument than is desirable.

80. More satisfactory results are usually obtained by employing other forms of resistance, five or six ordinary incandescent lamps placed in series, frequently being used for this purpose. Any of the common forms of fittings, such as sockets,* etc., may be used satisfactorily.

It is customary to connect the series of lamps directly from the line (trolley wire, etc.) to ground or the running rails, and to connect the circuit to be operated *in multiple* with the lamp nearest to the ground connection. Thus when this circuit is open, the voltage at its terminals is not dangerous, as would be the case if it were connected in series with all of the lamps, instead of in multiple with one of them.

81. *Fuses* of either the cartridge or link type are usually provided to prevent an excessive flow of current in case of

***Marine Sockets* (see **Magnetism and Electricity**—*Electric Lighting*) may be used to good advantage.

short circuit, and also *snap* or *knife switches* so that the propulsion current connections may be opened, when it is necessary to work about the apparatus.

82. An arrangement of resistances for reducing the voltage as just described, known as a **high voltage adapter,** is shown in Fig. 34. Two resistance rods 1 and 2, made of graphite, are employed, producing a result similar to that obtained by connecting the lamps in the manner explained in Art. 80.

Rod 1, which has a resistance of about 1,500 ohms, represents all of the lamps except the one connected in multiple with the operated circuit, which is represented by rod 2, having about 300 ohms resistance.

Fig. 34

The high voltage circuit is connected to binding posts 3 and 4, and the operated circuit to posts 5 and 6.

The knife switch serves as a cut-out for the high voltage circuit, and the fuses 7 and 8, guard against an overload.

83. In some instances the two resistances are connected in series with the operated circuit, in order to reduce the voltage on this circuit. Of course, with this arrangement a dangerous potential is maintained across the operated circuit when opened.

KEYS AND CUT-OUTS

84. When crossing alarms are located near stations or at other points where trains are liable to stop, it is sometimes advisable to arrange keys at these point
when trains stop, the alarm may be cu
desired, and again started when necessa

85. A form of *spring key,* known as **a strap key,** which may be used for this purpose, is illustrated in Fig. 35. This key is made of a

heavy flat brass or phosphor bronze spring, securely fastened to the base at one end, and being free to move between two contact points as shown. The contact points are fitted with platinum, and plates of this material are attached to the spring opposite the points. The two outside binding posts are connected to the contacts by wires beneath the base, one to the normally open and the other to the normally closed contact.

Fig. 36

86. Other types of keys which may be employed for this purpose, are shown in Figs. 36-38.

The type shown in Fig. 36, employs brass contact pieces, the spring being bent in such a manner as to provide a sliding contact.

It will be noted, in Fig. 37, that the ends of the springs are cut into four parts, and are so arranged as to give a sliding contact, thus tending to keep them clean.

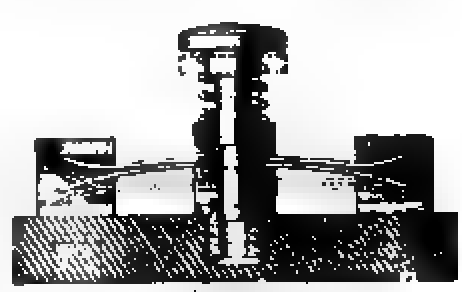


Fig. 37

The key illustrated in Fig. 38, is sometimes provided with a cast iron cover.

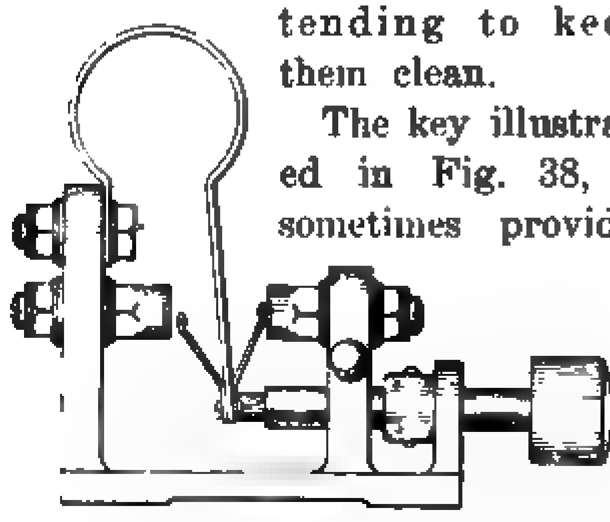


Fig. 38

87. The types of keys shown in Figs. 35-38, are also employed to test the operation of the bell,* although the form of spring keys, known as **push buttons** are frequently used for this purpose.

*See Art. 6.

88. In some instances a *cut-out switch* is installed in the alarm circuit, so that if the bell is ringing continuously, being out of order, it may be stopped (Art. 98).

Single point button switches,* or **single throw knife switches**** are generally used for this purpose.

BATTERIES

89. The track circuits are furnished with current from the types of batteries described in *D. C. Track Circuits,* although storage cells are seldom used in crossing alarm work, as the means of charging is generally not convenient.

Other circuits, if normally closed, employ gravity cells, and if normally open, sal-ammoniac or dry cells, while caustic soda or potash cells are used with both types of circuits.

BATTERY SHELTERS

90. In many cases small buildings, Fig. 39, known as **battery houses,** are erected to contain batteries, also being used to shelter

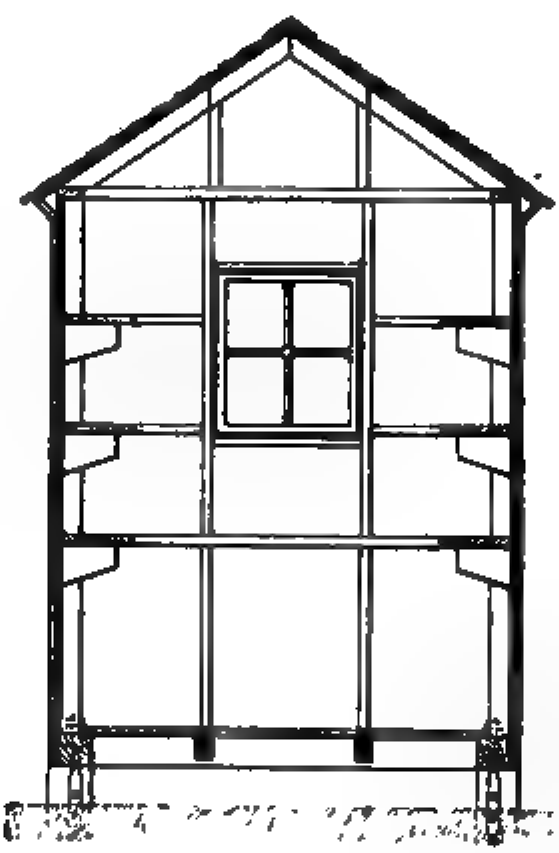


Fig. 39

*See **Magnetism and Electricity,** Fig. 152.
**Known as *baby knife switches*

relays, as already mentioned, or other instruments, and as a place for storing material.

For caustic soda or potash, or sal-ammoniac cells, these houses are usually warm enough when boarded only on the outside, but where cold weather is to be guarded against, they should be boarded on both sides of the studs. In such cases, a filling material, such as *charcoal* or *sawdust* is sometimes used to advantage, and it is also advisable to provide double doors and windows.

When working in a battery house the door is often allowed to stand open, in order to obtain sufficient light. To prevent it from being damaged by the wind of passing trains, a gate hook is provided, as shown, to hold it open.

91. When a battery house is protected by boarding on both sides and filling, it may be used for gravity cells, in moderate climates. In such cases lamps are used to advantage to heat the battery house when exceptionally cold weather is experienced.

In cold climates gravity cells for large batteries are generally kept in battery vaults.

92. Caustic soda or potash and sal-ammoniac cells, are sometimes placed in a battery cupboard suitably mounted on the bell post.

CIRCUITS

DOUBLE TRACK ARRANGEMENTS

93. Track Circuit Control: One of the most common forms of highway crossing alarm circuit for use on double track, is shown in Fig. 40. It will be observed that normally closed track circuits are employed, the alarm being controlled through

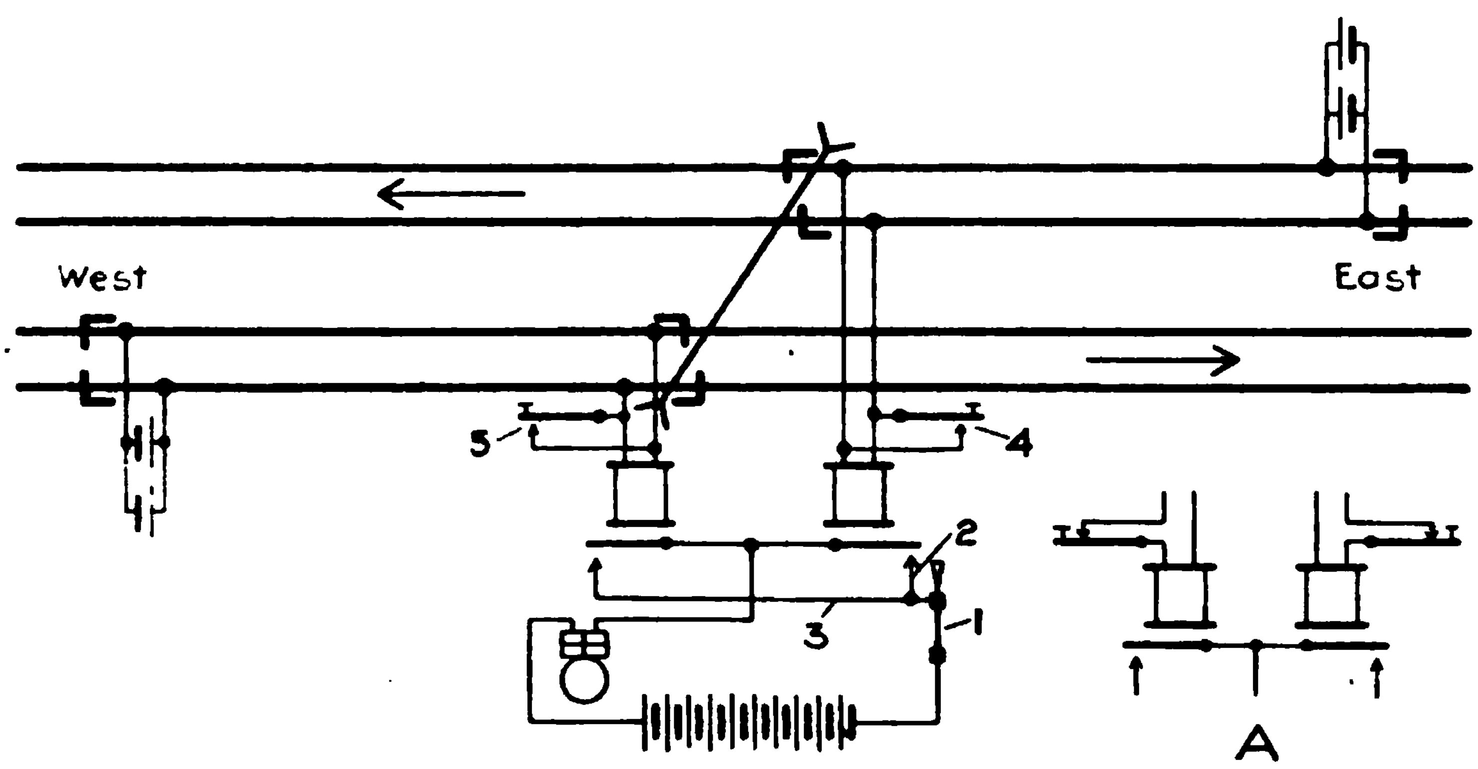


Fig. 40

back contacts on the track relays.* It will also be observed that the position of the track circuits is such that the alarm will operate *only* when trains approach the crossing in the direction of traffic** (indicated by the arrows).

94. As the alarm circuit is controlled by the back contacts of the track relays, connected in multiple, trains approaching the crossing on either or both tracks will operate the alarm.

Two bells, connected in multiple, are sometimes employed, especially where the highway crosses several tracks, a bell being located on each side of the crossing.

95. Lightning arresters may of course, be used as mentioned

*When more than one contact is provided, it is customary to control the alarm circuit through all of them connected in multiple, so that if one fails, the others will maintain the circuit. See **D. C. Relays.**

**See Art. 198.

in *D. C. Track Circuits,* but as some engineers do not favor their use, they are omitted from the circuit plans.

96. If a lamp is used in connection with the bell, it may be connected in multiple with it, thus burning continuously while the bell is ringing, or it may be operated by a contact on the bell armature, as shown in Fig. 41, in which case the lamp would emit a series of flashes during the ringing of the bell. When thus arranged the contacts 3—4 and 5—6, are so adjusted that the current will not be flowing in the bell and lamp circuits at the same time; that is, one set of contacts opens before the other set closes. This adjustment is desirable in order that the lamp, whose resistance is low, will not shunt the bell.

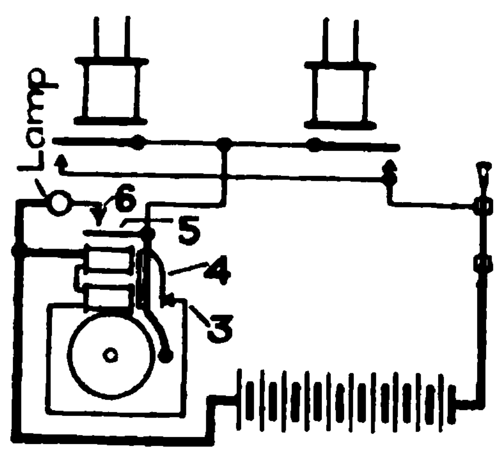


Fig. 41

97. It is customary to use from 5 to 18 volts on the alarm circuit, this depending upon the type of alarm employed.

With a number of cells connected in series, as shown in Fig. 40, a broken jar or a broken jumper, will cause a failure of the battery and consequently the bell will fail to ring upon the approach of a train to the crossing. Battery failures are also experienced owing to the corroding of the binding posts, especially with some types of sal-ammoniac cells.

To avoid this trouble, the batteries are sometimes duplicated as shown in Fig. 42. With arrangement A, a failure must occur in both sets to cause a failure of the bell. This is also true of arrangement B, which in addition, has the advantage that the failure must occur in two *opposite* cells.

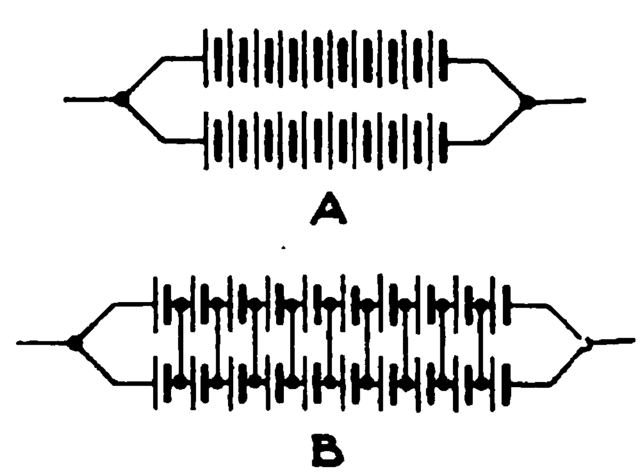


Fig. 42

98. It will be observed in Fig. 40, that a cut-out switch 1, is provided. This is sometimes considered desirable in order that the alarm circuit may be opened in case one of the track relays fails to pick up, causing the alarm to operate contin-

uously. Of course, the crossing should be guarded by a temporary flagman while the alarm is cut out.

In some instances two switches are provided, one being cut into each of the leads 2 and 3. This arrangement makes it possible to continue the use of the alarm for one track while the other is out of service.

99. The *spring keys* 4 and 5, shown in Fig. 40, are often employed as a means for testing the alarm.* It will be noted that the effect of closing one of the keys is the same as that produced by a train on the circuit.

Instead of the keys being connected in multiple as shown, they are sometimes cut in series with the relay as illustrated in sketch A, normally closed keys being necessary under these conditions.

When the series arrangement is used in connection with interlocking relays, a dangerous condition might be caused by resistance in the key contacts.**

In some cases *knife switches* are employed for this purpose instead of spring keys.

100. When it is desired to operate alarms at two crossings located close together, the arrangement illustrated in sketch A, Fig. 43, is often employed.

It will be observed that *relayed track circuits* are used, and the alarm circuits so arranged that *both* bells start to ring at the same time, each one stopping as the rear of the train passes it. Of course, if there are trains on both tracks the bell at either crossing will continue to ring until the rear end of both trains have passed it.

It is generally considered satisfactory to start both bells ringing at the same time, if the crossings are not more than 1,000 ft. apart.

101. The bells are, in some cases, supplied with current from the same battery, the wiring being arranged as shown in sketch B, Fig. 43.

The wires between the crossings are generally strung on a pole line and lightning arresters provided as indicated. Of

*See Arts. 6 and 87.
**Explained in Art. 220.

course, if these wires are run in trunking the arresters will be omitted. In this and other similar cases, it is not desirable to use fuses in connection with the lightning arresters, for if

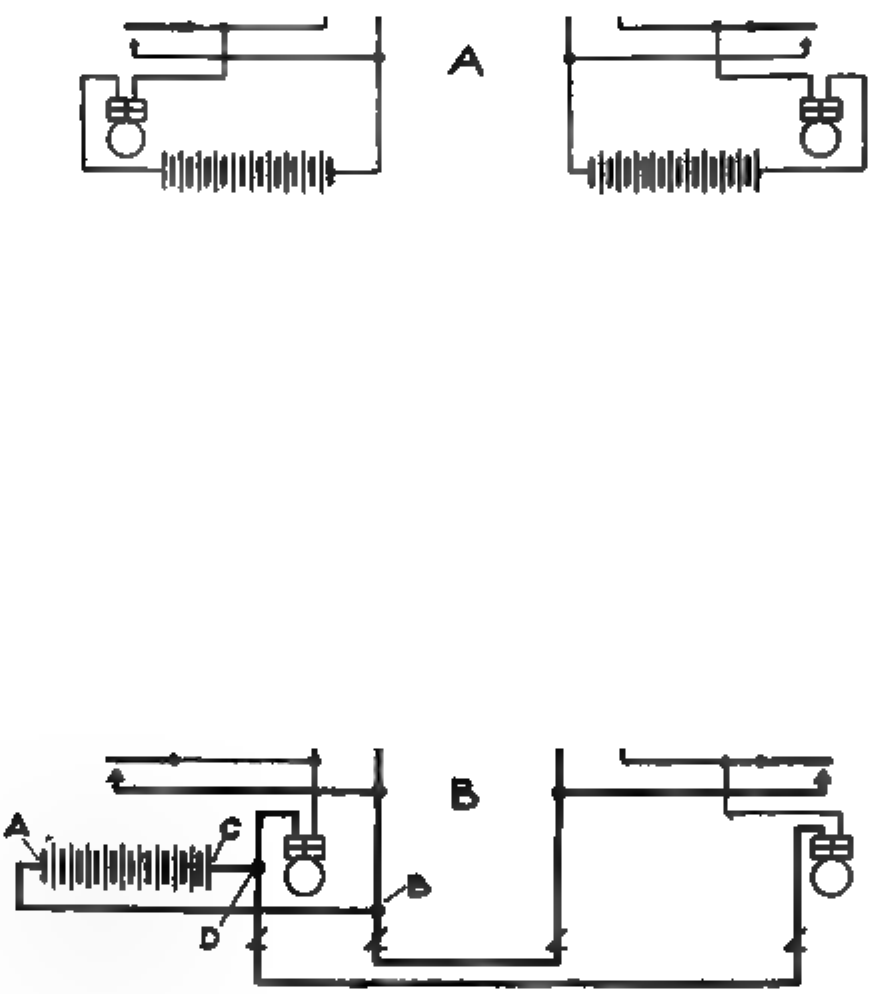


Fig. 42

blown, they will produce a dangerous condition by opening the bell circuit and thus preventing the bell from ringing upon the approach of a train.

As will be seen, the *two* bell circuits use the *same* wires between points A and B, and points C and D. The wires thus

used, are known as *common wires,* as they are employed as common conductors for more than one circuit. While in this case, only those portions of the wire between points A—B and C—D, are used to carry the current for both instruments, and are therefore the only parts that are literally common wires, it is customary to indicate these portions of the wire *together with their branches,* by heavy lines, as shown. This readily distinguishes them from the other wires and simplifies considerably, the tracing of circuits on complicated plans. It is customary to indicate by heavy lines only such wires as are *directly* connected to the source of energy.

102. In order to distinguish between the two common wires, the *positive* wire A—B and its branches is usually termed the *battery wire,* while the *negative* wire C—D and its branches is known as the *common return wire.**

In many instances, the common wire is used as a path for current from two or more batteries. In such cases it is the usual practice to connect the *negative* terminals of all the batteries to the common wire, although in a few instances all the *positive* terminals are connected to it. In rare cases the positive terminals of some batteries and the negative terminals of others, are connected to the common wire.

The common and battery wires may or may not be of a larger size than the other wires, this depending upon the amount of current they are required to carry.

103. The arrangement shown in Fig. 43, is sometimes used to advantage, at points where three crossings are located close together, the track circuits being relayed at each crossing.

104. Where two crossings are so far apart that it is not desirable to start both alarms operating at the same time, yet the distance between the crossings is not sufficient to allow *separate* track circuit control to be provided for each alarm, the method illustrated in Fig. 44, is employed.**

With this arrangement the alarm at crossing A, starts to

*This term is generally shortened to simply *common wire*, which as used hereafter will signify the common return wire.

**It should be noted that the circuits for only one track are shown.

operate when the train passes point X, and the alarm at crossing B, when the train passes point Y. The distance from Y

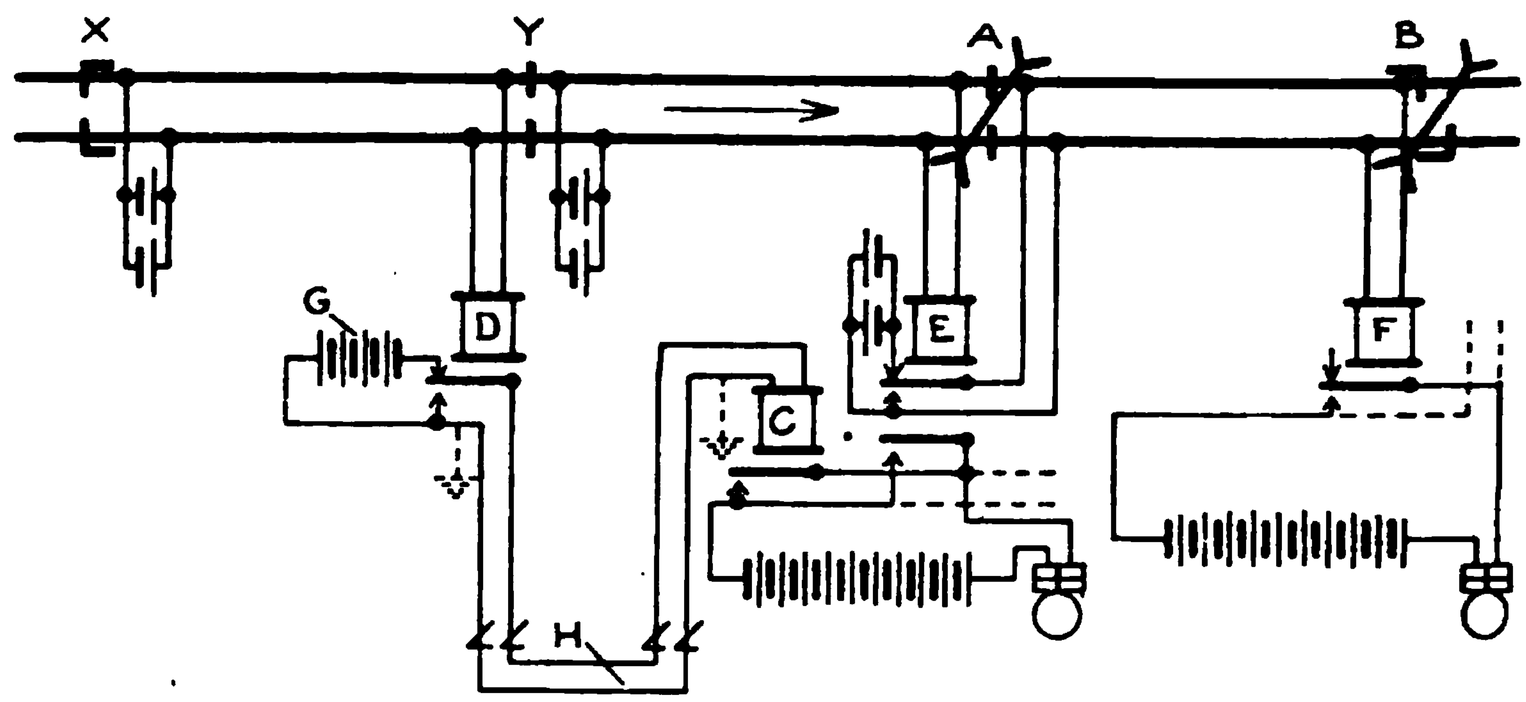


Fig. 44

to B is about equal to that from X to A, thus both alarms operate for about the same length of time.

105. The control of the alarms is accomplished in the following manner. It will be noted that *line relay* C, whose back contact closes the alarm circuit at crossing A, simply repeats the position of *track relay* D; therefore, when the train passes point X, relay D, and consequently relay C, are de-energized, thus completing the alarm circuit at this crossing. When the train passes point Y, track relays E and F, are de-energized, the former completing a *multiple* path for the alarm circuit at crossing A, and the latter completing the alarm circuit at crossing B. As the rear end of the train passes point Y, relay D is picked-up and *line battery* G again energizes line relay C, but as the alarm circuit is also controlled through track relay E, this alarm continues to operate until the rear of the train passes the crossing.

The dotted lines shown in connection with the alarm circuits, indicate the leads to the back contacts of the relays for the opposite track.

106. The *line battery* is usually composed of caustic soda or potash cells, although gravity cells are often employed. The voltage of this battery is sufficient to provide a proper working margin above the pick-up point of the line relay.

The *line relay* is usually wound to 50 or 100 ohms, although in some cases lower resistances are used.

107. In some instances, instead of installing a line wire to act as a *return*, a *ground* or a *rail return* is employed. For example, in Fig. 44, line wire H may be omitted, ground connections being installed as indicated by dotted lines, or a return path being provided by connecting to one of the rails between the insulated joints at points Y and A, making this rail a common conductor for both the track and the line circuits.

108. It will be observed in Fig. 44, that the line battery and line relay are located at the opposite ends of the circuit. The object of this is to guard against the improper energization of this relay, which would probably occur, in the case of a cross in the line wires, if both battery and relay were located at the same end of the circuit. When arranged as shown in the illustration a cross in the line would simply shunt relay C.

109. It is apparent that if test keys* are installed at relays E and F, they will only indicate that a portion of the apparatus is in proper working order. For instance, a test made at relay E, would not indicate the condition of relay D. A test key may be installed in the line circuit to indicate the condition of relay C, but to ascertain whether the alarm at crossing A operates when relay D is shunted, or the alarm at crossing B when relay E is shunted, their operation should be observed when a train is approaching. Therefore it is usually desirable to omit test keys in such cases.

110. When three or more crossings are so located as to require *overlapping* alarms, the arrangement shown in Fig. 45, may be employed. As will be seen this is a development of the circuits shown in Fig. 44.

The alarms at crossings X and Y, start when the train passes point W, and that at crossing Z, when it passes crossing X, each of them stopping when the rear of the train passes it.

*See Art. 99.

If it is desired to start the alarm at crossing X, before the train reaches point W, the apparatus shown dotted is installed. . will be observed that the circuits may ·epeated for any number of crossings, .g the line relay at each crossing except last, at which the alarm is controlled a relayed track circuit.

11. As relay A is supplied with cur- . from a bell battery, it is wound o a resistance suited to its voltage, 00-ohm relays being commonly used for his purpose, although relays of higher esistance, are sometimes more econom- cal, as regards current consumption.

112. It is often necessary to control a crossing alarm by track circuits which are also employed to control other signal apparatus. A method of accomplishing this is illustrated in Fig. 46.

It will be observed that the alarm ·cuit is controlled by the track cir- it extending from point A to the ossing, whereas the signal apparatus, which is foreign to the alarm circuit, is controlled by relay B, this relay indicating the presence of a train between point C and the crossing.

h *polarized* relayed track circuits are polarized feature may be omitted if ·dinary neutral relayed track circuits l.*

y D may be momentarily de-ener- n the pole changer is reversed to e polarity of the track circuits, thus

*This holds true for circuits shown hereafter, except as noted otherwise.

tending to cause the bell to ring, a *slow stroke gong* is sometimes employed.

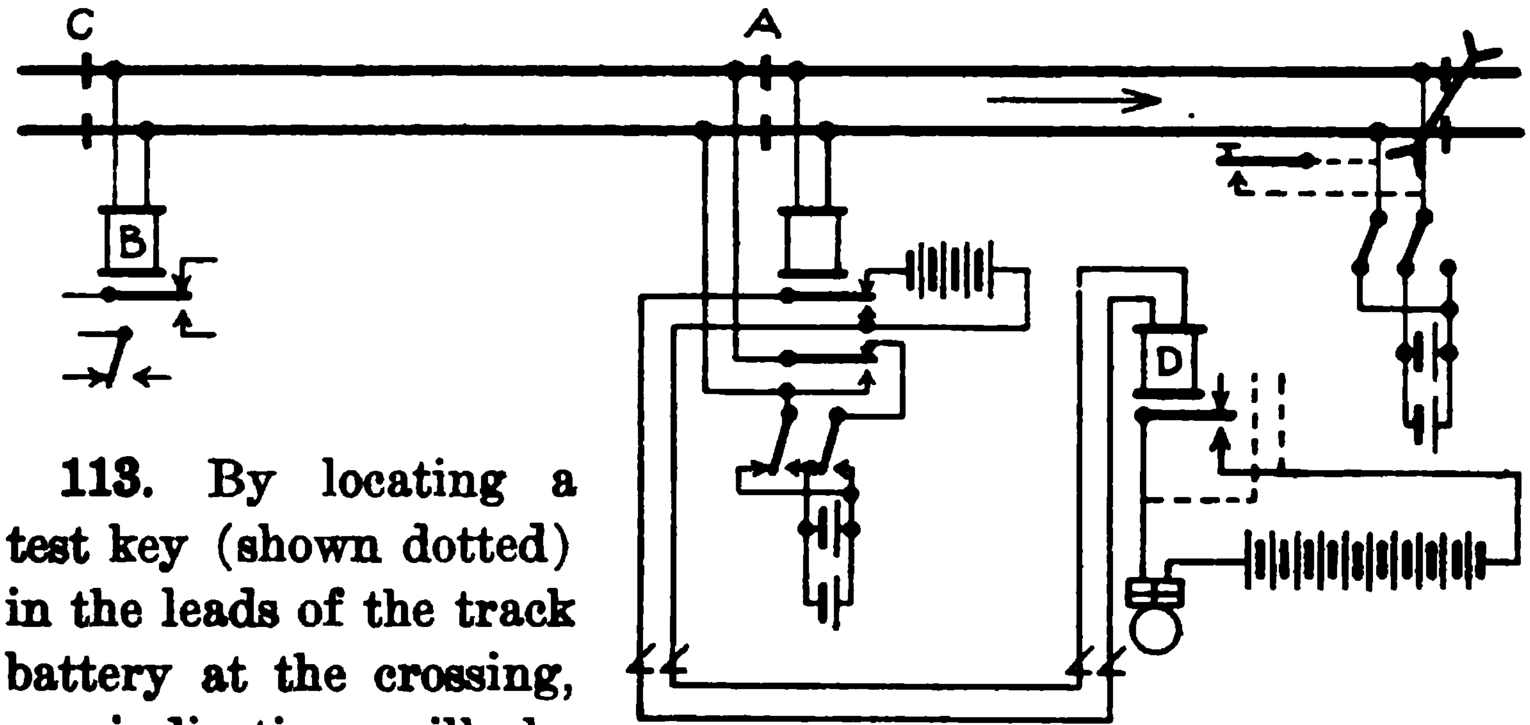


Fig. 46

113. By locating a test key (shown dotted) in the leads of the track battery at the crossing, an indication will be given of the condition of all circuits controlling the alarm. However, care must be taken to select a suitable time to test the circuits, as the de-energization of relay B, which often controls a signal, may cause delays to traffic.

114. The circuit arrangement shown in Fig. 47, is adapted to cover the same conditions as explained in connection with Fig. 46.

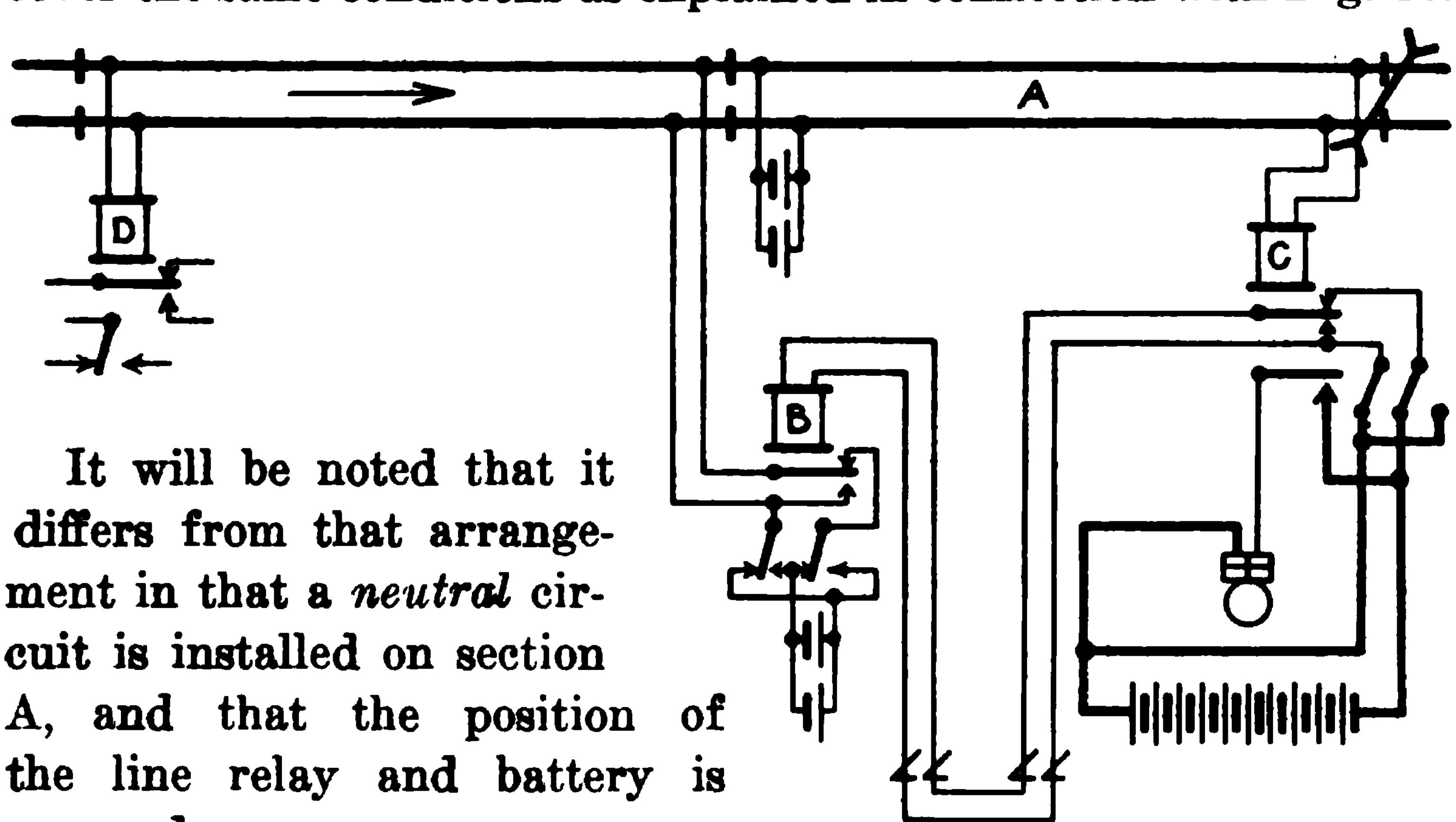


Fig. 47

It will be noted that it differs from that arrangement in that a *neutral* circuit is installed on section A, and that the position of the line relay and battery is reversed.

Line relay B, repeats the positions of track relay C, being used to relay the track circuit.

The circuits shown in this illustration are so arranged that there is no tendency to cause the bell to ring improperly.

115. Where, as in Fig. 47, the bell battery is also used to supply current to line circuits, a check on the condition of the battery is obtained. For instance, the bell circuit would not give any indication of a battery failure until a train entered the ringing circuit, at which time the bell would *fail to ring,* but relays B and D would show up this condition by remaining de-energized.

116. In Fig. 48, is shown an arrangement, in which the circuit for the signal apparatus, foreign to the alarm, is carried

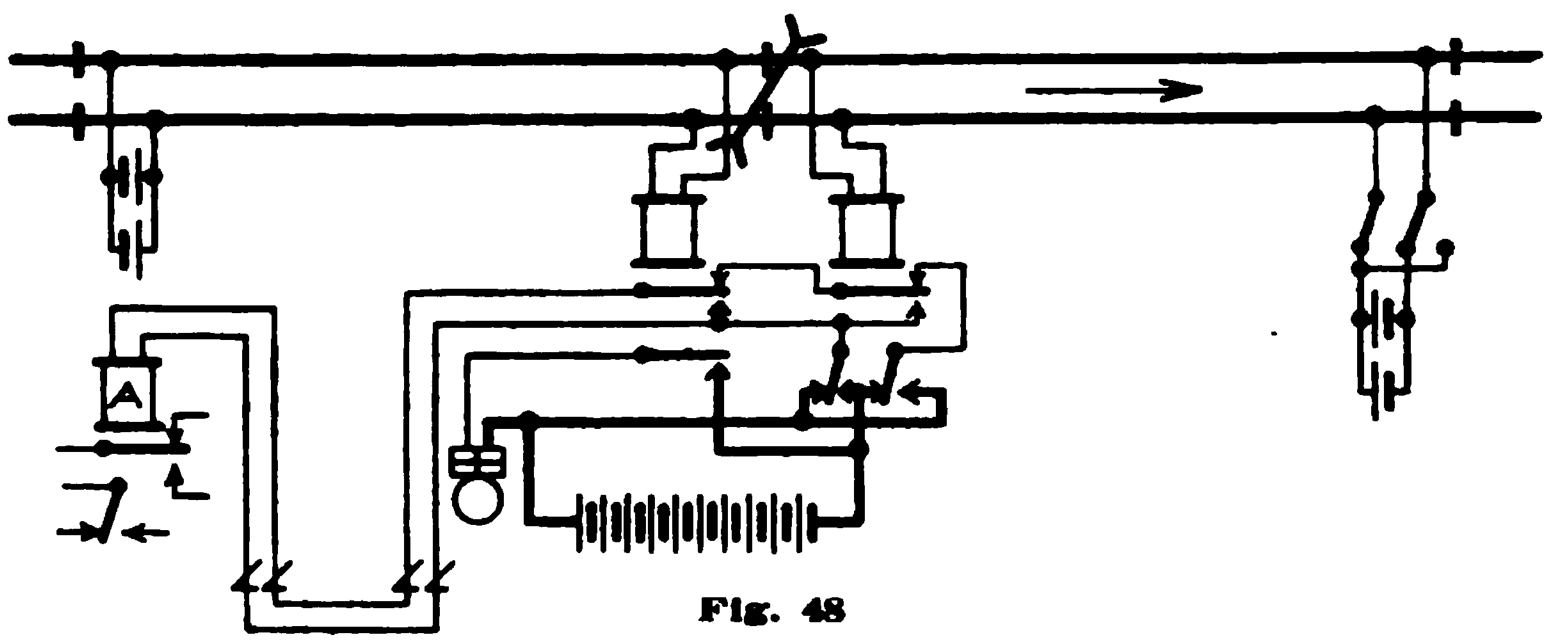


Fig. 48

through contacts on line relay A, which is in turn controlled by the track relays.

117. To avoid, as much as possible, complications in the circuits, the length of the track circuit controlling the alarm, may be varied within reasonable limits, thus allowing it to be adapted to suit local conditions.

118. In Figs. 46-48, it will be observed that the track circuit which operates the crossing alarm, is at one end of the track over which the control of the other signal apparatus is extended. It is however, often necessary to operate a crossing alarm by a track circuit located within such a section, but at some distance from either end of it. One method of doing this, which is suitable for use with neutral circuits, is illustrated in Fig. 49, in which the alarm is operated by track circuit B. In this instance line relay D is controlled by track circuits B and C, and in turn controls track circuit A. Therefore, relay E, which controls the apparatus foreign to the

crossing alarm, indicates the presence of a train on circuits A, B or C.

Fig. 49

A similar arrangement to that shown in Fig. 49, might be employed with polarized circuits, but it is not generally considered good practice to relay a polarized track circuit more than once on account of the difficulty experienced in maintaining circuits controlled through polarized contacts.*

119. It will be observed that the *common wire* is extended to one terminal of relay D, forming one side of the line circuit. The other side of this circuit, that is, the wire which carries current from the *battery wire* to the other terminal of relay D, and is broken through the upper contacts on the track relays at the crossing, is known as the **control wire** for relay D. In other words when one or more contacts are employed to control an instrument, it is customary to have all the controlling contacts placed in one side of the circuit, the battery wire being carried to the first, and the *control wire* beginning there and being carried through all other contacts to the controlled instrument, the circuit then returning to the battery on the common wire.

120. Where it is desired to employ polarized circuits at locations similar to that shown in Fig. 49, the arrangement shown in Fig. 50, may be used. As will be seen line relay D is at the opposite end of circuit A, to that shown in Fig. 49, its

*See D. C. Relays.

circuit being carried through a contact on track relay E, as well as through contacts on the track relays of circuits B and

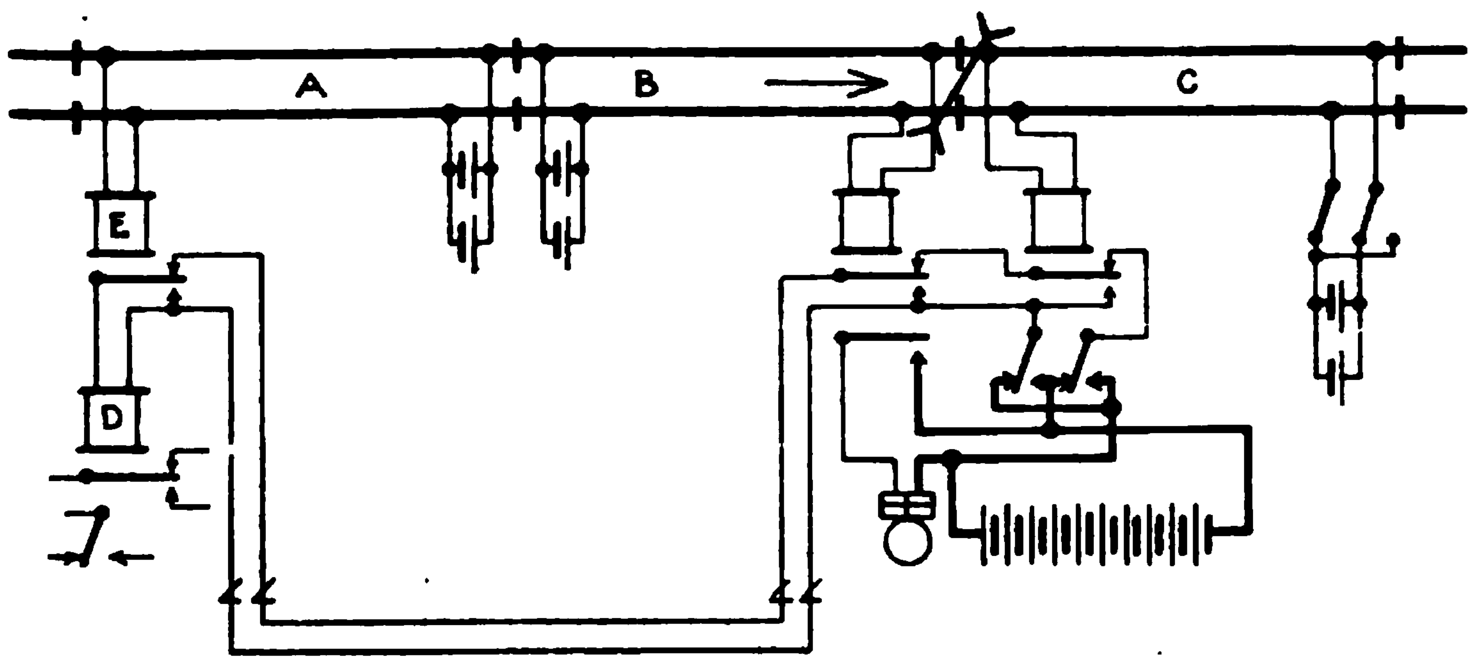


Fig. 50

C. Of course, the apparatus controlled by relay E in Fig. 49, is in this case controlled by relay D.

121. When it is desired to operate crossing alarms at *two* adjacent crossings, in territory where the track circuits con-

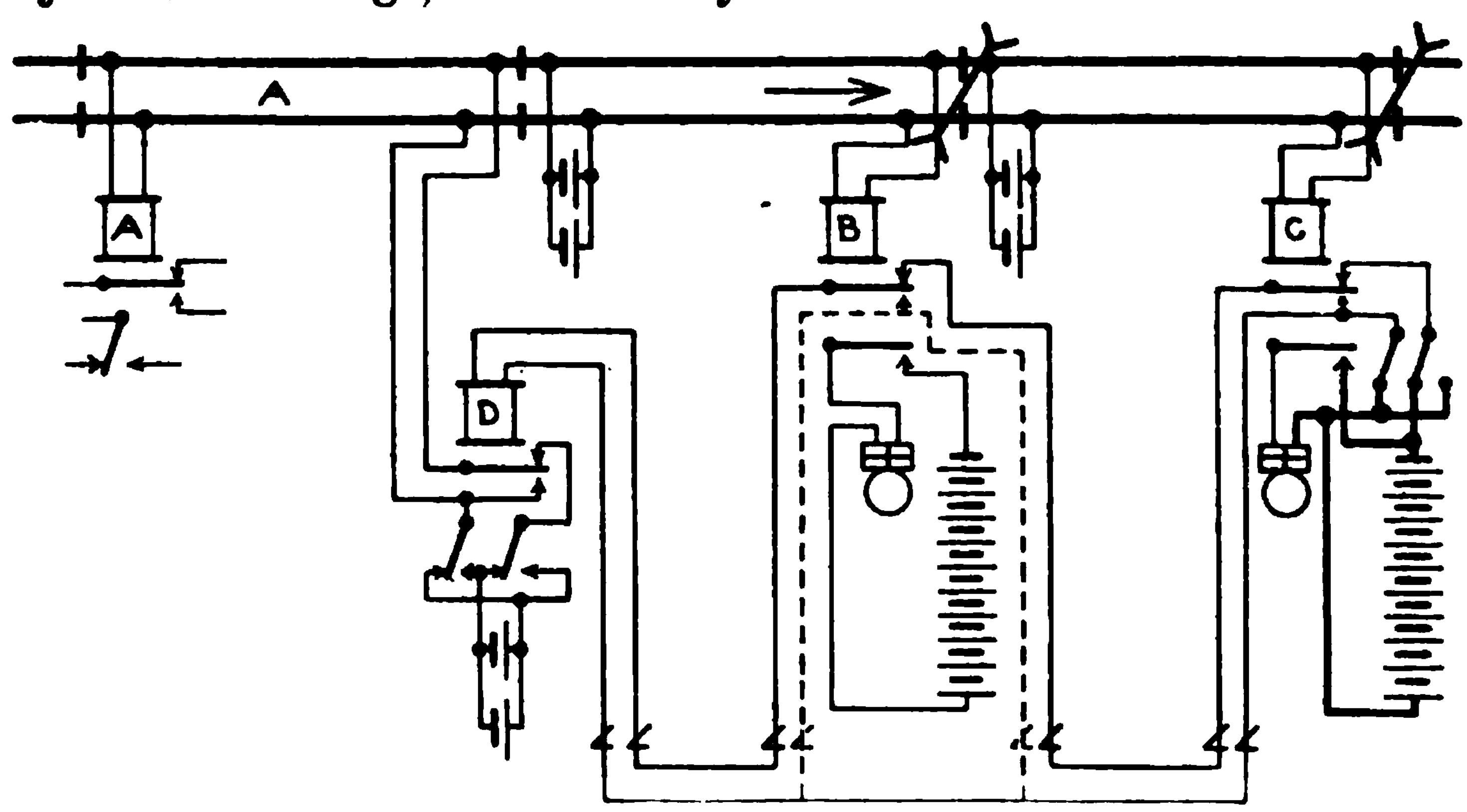


Fig. 51

trol other signal devices, the arrangement illustrated in Fig. 51, may be employed.

It will be noted that line relay D is controlled by track relays B and C, and that it controls track circuit A.

122. If conditions require it, track circuit A may of course,

be omitted, the circuits controlled by relay A, being carried through line relay D.

The return line wire is not usually carried to the back contact of relay B, but may be so arranged, as indicated by dotted lines, if the shunt protection against crosses is desired.

123. An adaptation of the arrangement shown in Fig. 50, for use where alarms are to be installed at two adjacent crossings, is illustrated in Fig. 52.

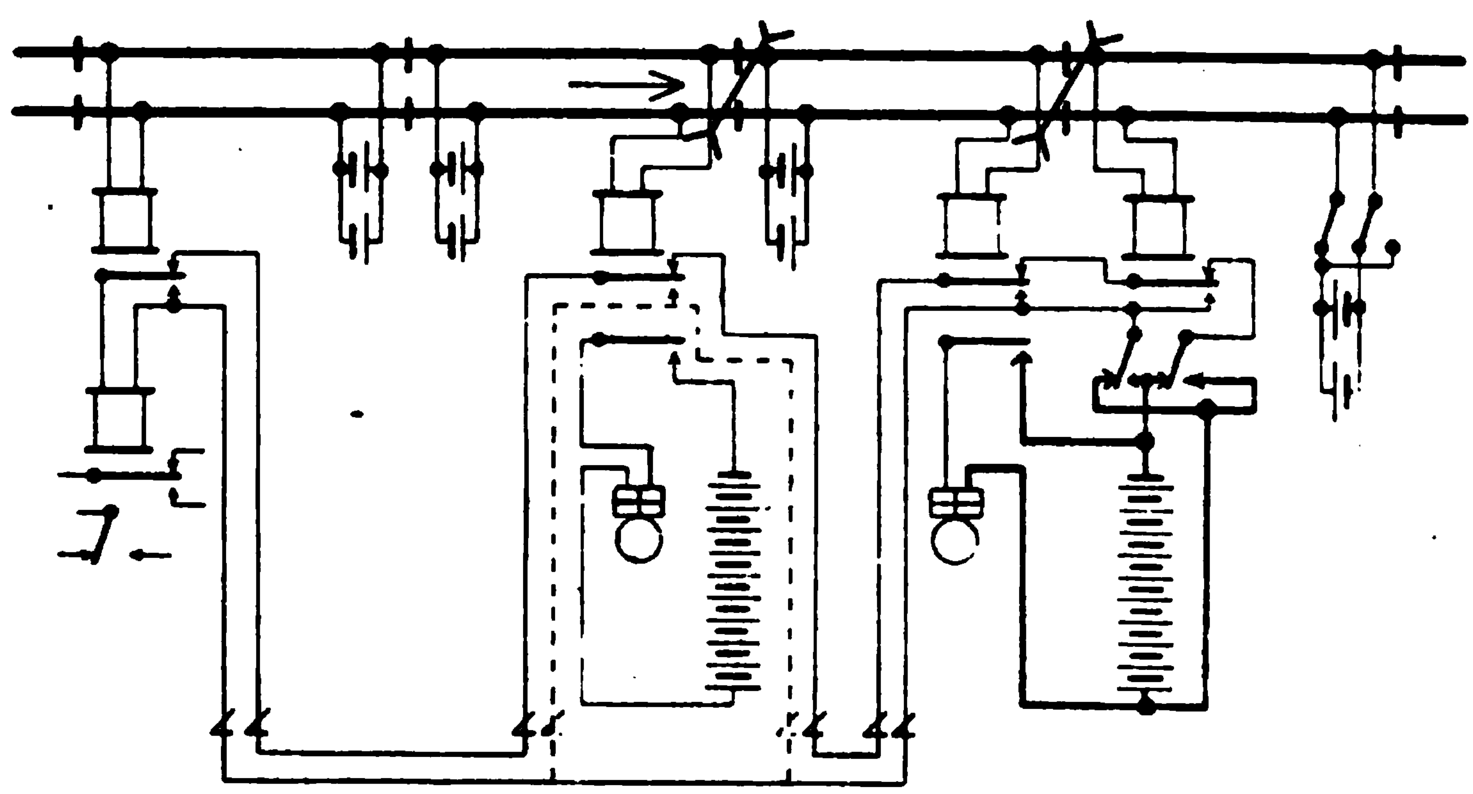


Fig. 52

124. The arrangement illustrated in Fig. 53, is an adaptation of that shown in Fig. 43, the track circuits which control the

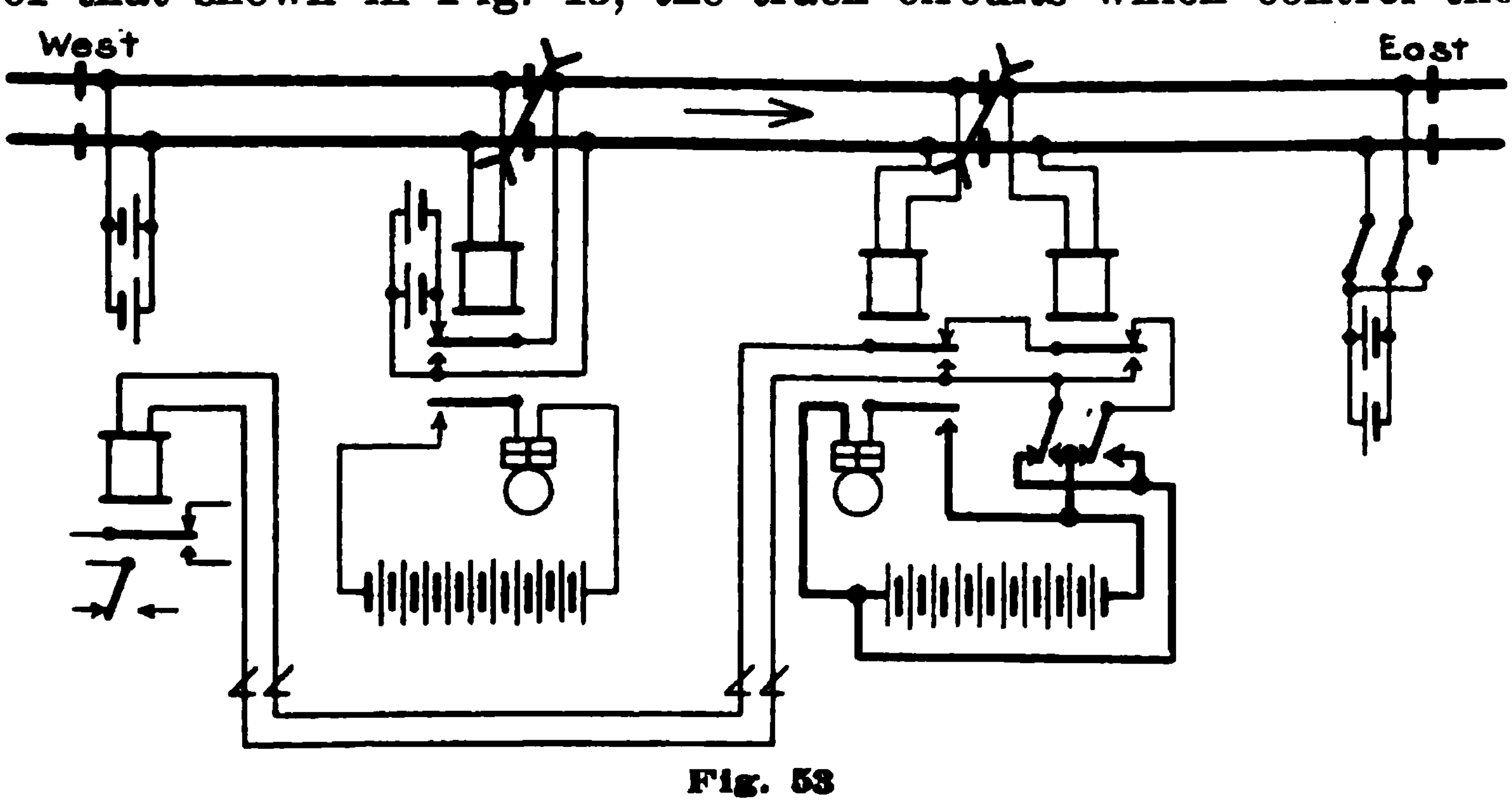


Fig. 53

crossing alarms, also controlling other signal devices, the control of which extends east of the crossings.

125. A similar adaptation to that just described is illustrated in Fig. 54, the circuits being a development of those shown in Fig. 44.

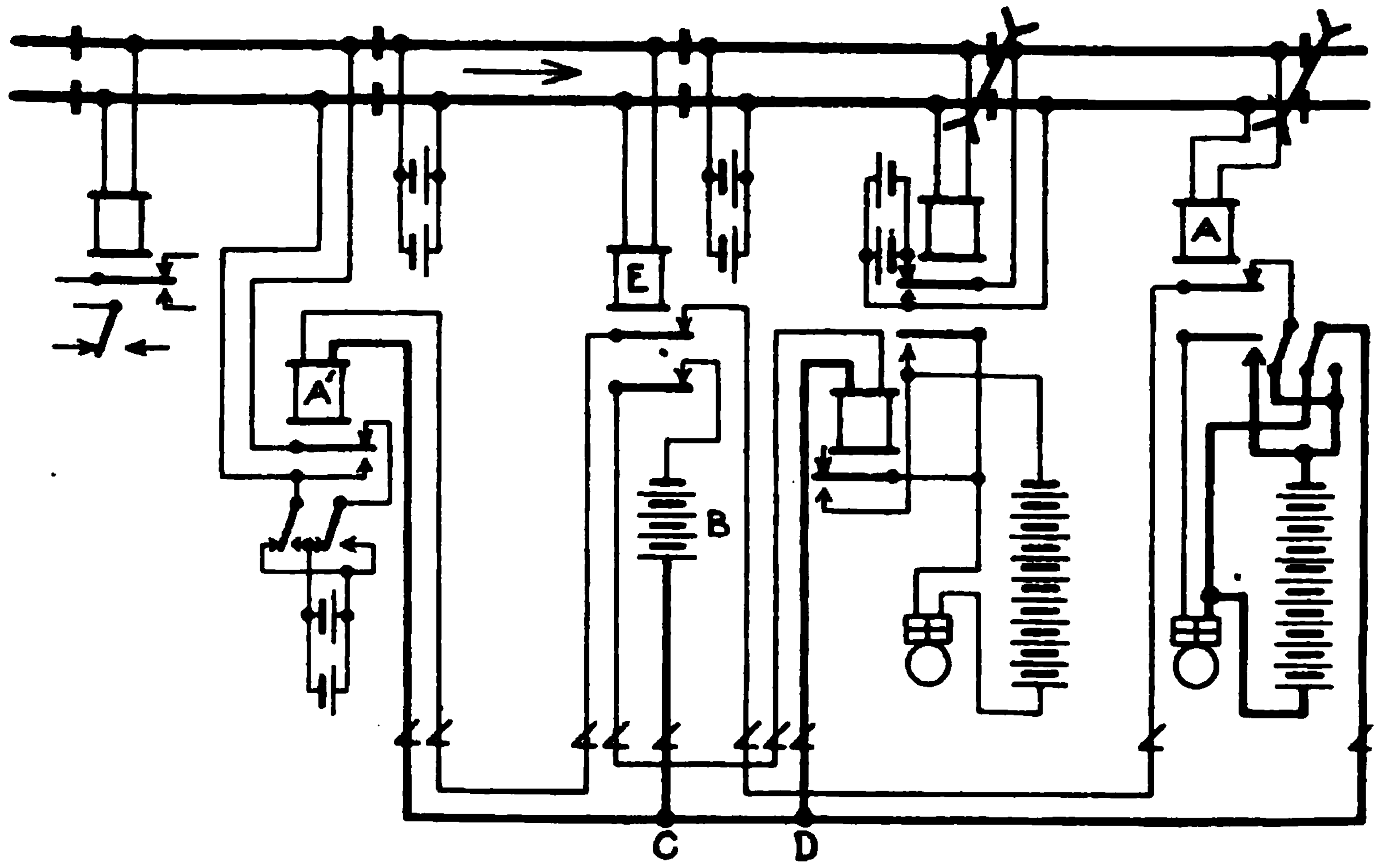


Fig. 54

126. It will be observed, that a *common return wire* is used for the two line circuits, and that the *back contact shunts* are omitted from these circuits. This is so arranged to avoid the possibility of line relays or other apparatus, being falsely energized as a result of a break or unusual resistance in the common wire, or on account of drop in potential on this wire, due to its being *overloaded** with current.

127. One of these conditions is illustrated in Fig. 55, in which the common return wire for *two* line circuits is connected

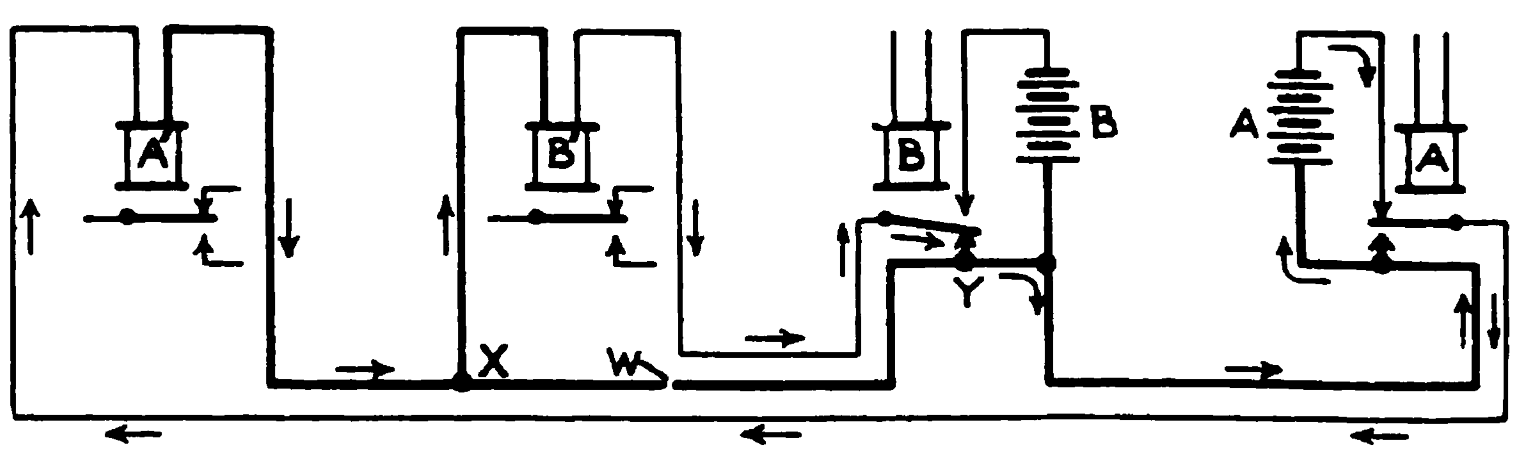


Fig. 55

*The term *overload*, as used here, does not mean that the current flowing in the common wire exceeds the amount which it can safely carry without undue heating (as mentioned in **Magnetism and Electricity**), but is current above the amount which it can carry without causing a dangerous drop in potential.

to the back contacts of the controlling relays in a manner similar to that employed in connection with the *separate* line circuits shown in Figs. 44-53.

With controlling relay B, de-energized, relay B′ should also be de-energized, but with a break in the common wire at any point between joints X and Y, for instance at W, relay B′ is placed in series with relay A′ and consequently energized by current from battery A, flowing through the path indicated by the arrows.

If the conditions should be reversed, relay A being open and relay B closed, then relay A′ would be improperly energized by current flowing from battery B, in the direction opposite to that indicated by the arrows.

It will be seen that unusually high resistance instead of a break, would tend to produce the same effect.

128. Another condition which may cause the improper energization of apparatus, through back contact shunts, is the **overloading** of the common wire.

129. A circuit arrangement where such a condition may exist, is shown in Fig. 56. If the resistance of the common wire between points A and B is 3 ohms, and there is a current of 2 amps. flowing from point C to D, there would be a potential difference of 6 volts between points A and B, providing the circuit for relay E was open, that is, the back contact shunt on relay F, omitted.

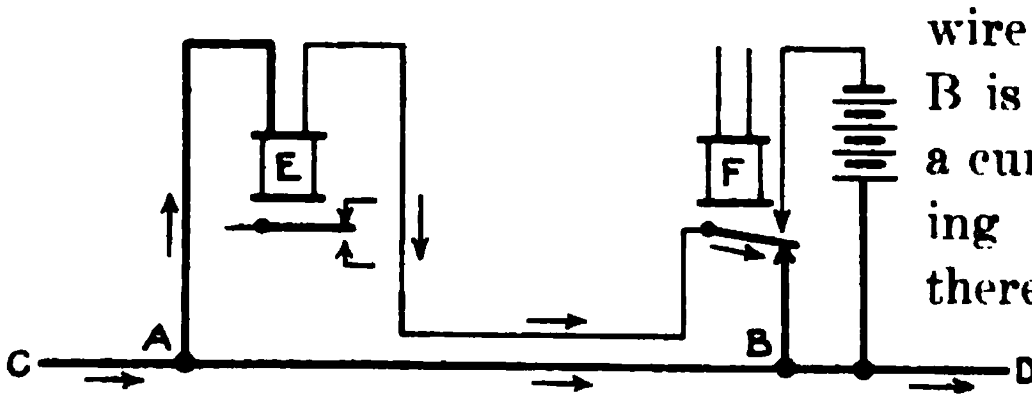


Fig. 56

Now, assuming the resistance of relay E to be 100 ohms, and also assuming the circuit for this relay to be closed through the back contact of relay F as shown; then, an additional path is provided which, allowing 5 ohms for the resistance of the wiring, has a total resistance of 105 ohms. By combining this resistance with that of the common wire, the joint resistance of the two paths from A to B, is found to be 2.92 ohms. As it is assumed that 2 amps. is flowing from C to D, the drop in potential between points A and B, would be 5.84 volts. This voltage would cause

a current of 55.6 mil-amps. to flow through relay E which, being considerably above its pick-up point would energize it improperly.

130. Reference to Fig. 54, will indicate that, although a back contact shunt *cannot* be used at controlling relay A, on account of improper energization of relay A′ by battery B, in case of a break or unusually high resistance in the common wire between points C and D, nevertheless they *can*, if desired, be employed at controlling relay E, without producing any such dangerous conditions.

131. However, it is not always easy to determine whether or not a back contact shunt may safely be employed. Therefore, although, as just noted, it is possible in some cases, to safely employ back contacts to obtain shunt protection where common return wires are used, it is the general practice, in such instances, especially where additional circuits are likely to be installed using the same common return wires, to forego their use, as the advantage gained would not compensate for the resulting complications.

132. Another instance of trouble which may be caused by an *overloaded* common wire is illustrated in Fig. 57. In this case the back contact shunt is omitted, but the drop in voltage on the common wire acts as a *counter E.M.F.*, tending to *oppose* the battery. Thus, if the resistance of the common wire between points A and B is 2 ohms, a current of 2 amps. flowing from point C to D, will cause a drop in potential, between points A and B, of 4 volts, which would neutralize the 4 volts generated by battery G, and thus cause relay E to improperly release its armature.

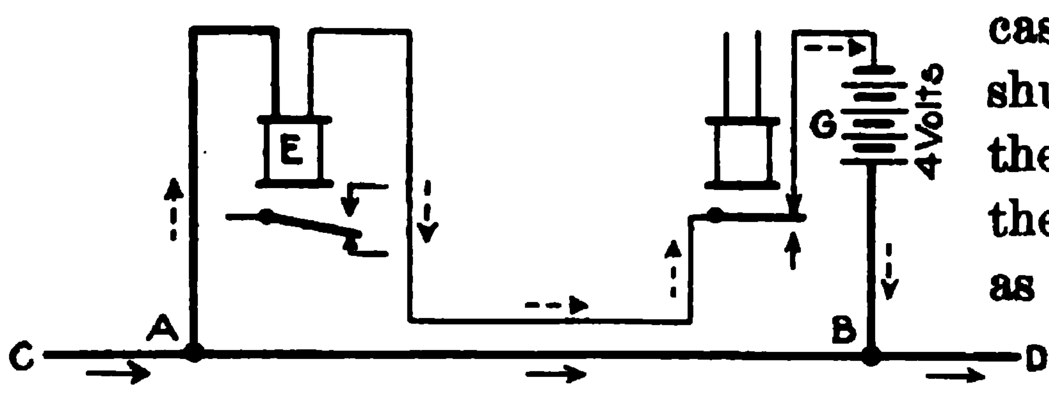


Fig. 57.

133. With a greater difference of potential between points A and B, enough current might flow through the circuit for relay E, in the *reverse* direction as indicated by the dotted arrows, to cause it to again attract its armature after having

released it. Such a condition may prove dangerous in cases where E is a polarized relay, as the change in polarity would,
polarized armature, causing
ication.

se be understood that a break
gh resistance in the common
re is likely to produce the
me effect.

134. As the amount of current
wing in the common wires gen-
ally varies considerably, fail-
es, of the character just de-
ribed, are usually intermittent,
and therefore are frequently difficult to locate. If, however, it is definitely determined that this is the source of the trouble, a larger common wire or separate circuits should be installed.

Fig. 58

135. In cases where the controlled apparatus which is foreign to the crossing alarm, is located *between* the point where the train starts the alarm and the crossing, the arrangement illustrated in Fig. 58, may be used.

In this instance relays A
the alarm and relays C and
devices, the bell beginning to
train passes point E.
arized track circuit is used on
hown, a slow stroke bell should
or the reasons stated in Art. 112.

136. It is not generally considered good practice to use a

fuse in lightning arrester G, as a break in the common wire caused by the blowing of the fuse, might produce conditions similar to those explained in connection with Fig. 57. If fuse protection is desired on the common wire, instead of one arrester at G, two may be employed, one at H and the other at J, at which points it will be noted that the common wire conducts current for only one circuit.

137. It will be observed in Figs. 46, 54 and 58, in which line relays control the bells, that a *separate* line relay must be

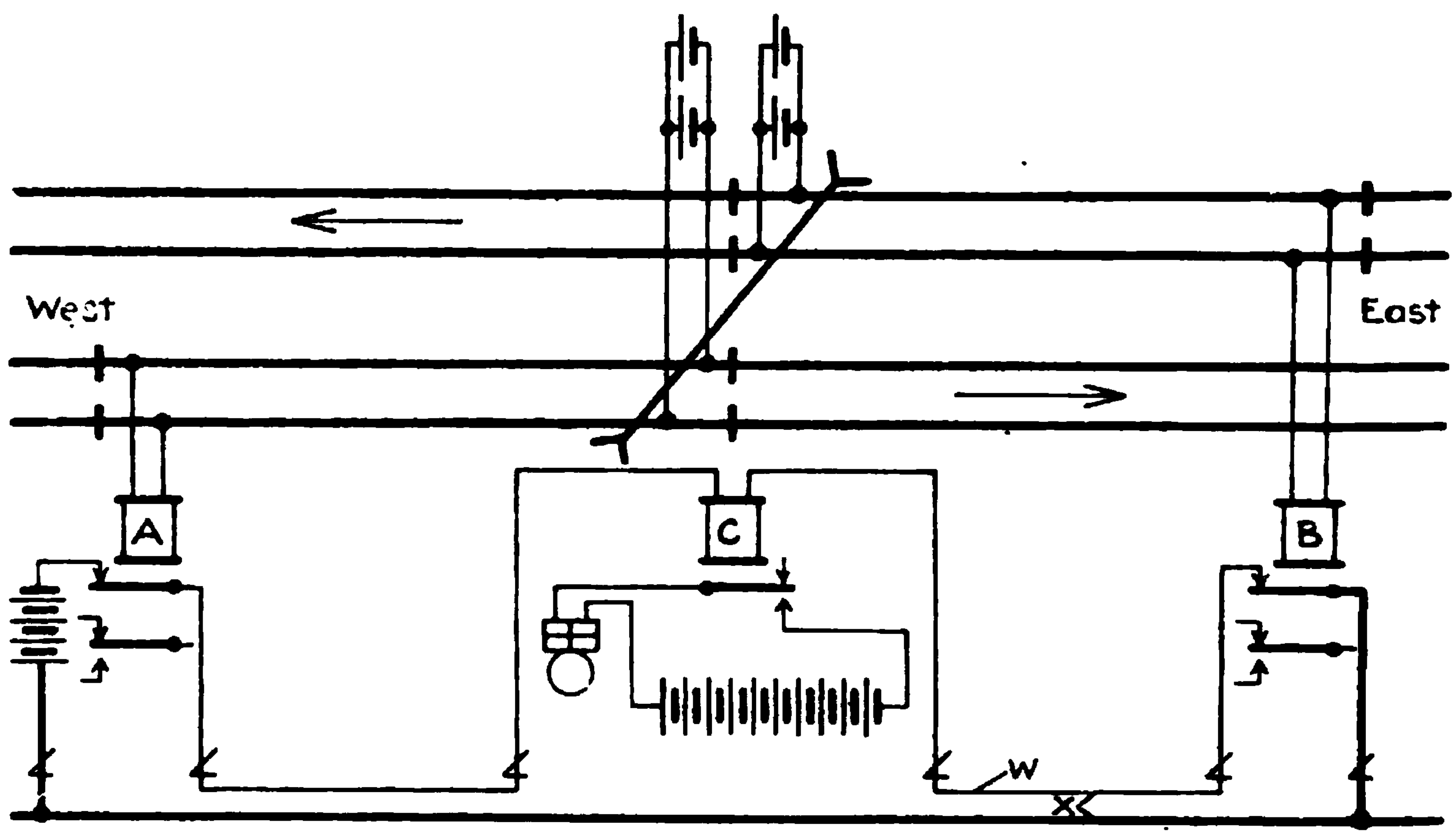


Fig. 59

provided for each track. For instance, in Fig. 46, line relay D controls the bell for train movements on the track shown, the dotted connections to the bell circuit being carried through contacts on another line relay, controlled by the track circuits on the opposite track (not shown).*

138. To avoid the use of one of these line relays the circuits are sometimes arranged as shown in Fig. 59. The same layout is here illustrated as appears in Fig. 46 (excepting the polarized feature of the track circuits) it being necessary to locate relays A and B as shown, owing to their controlling other signal apparatus. It will be seen that one line relay, C, controls the bell for train movements on both tracks.

*That is, assuming that the circuit arrangement is similar for both tracks.

With this arrangement trouble may sometimes be experienced with grounds or crosses. For example, if the line becomes crossed at point X, the bell would fail to ring for a west-bound train. Again, when a common wire is used as shown, similar trouble is likely to result from a ground on wire W, as the common wire in many cases is permanently grounded, while in other cases it may become grounded and remain so for a considerable length of time without being discovered.

139. A development of the arrangement shown in Fig. 59, for use at two adjacent crossings, is illustrated in Fig. 60.

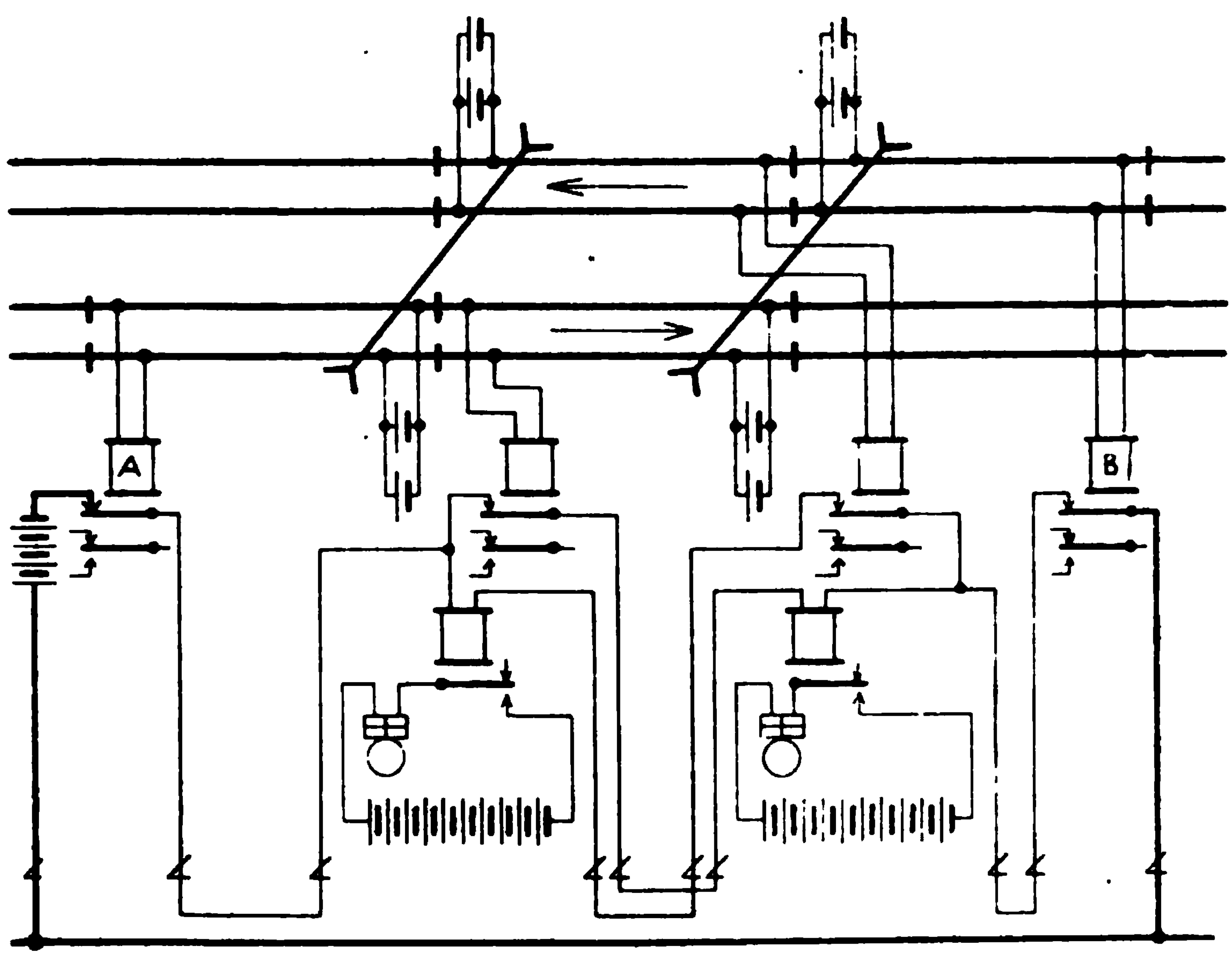


Fig. 60

It will be noted that one battery operates both line relays.

140. It sometimes happens that apparatus foreign to the crossing alarm but operated over the same length of track, is located *in advance* of the crossing instead of *in rear* of it. An arrangement for use in such cases, is shown in Fig. 61, in which relay A indicates the presence of a train between points W and Z, while the crossing bell rings only while the train is

between points X and Y. If desired, the polarized feature may of course, be employed with such arrangements.

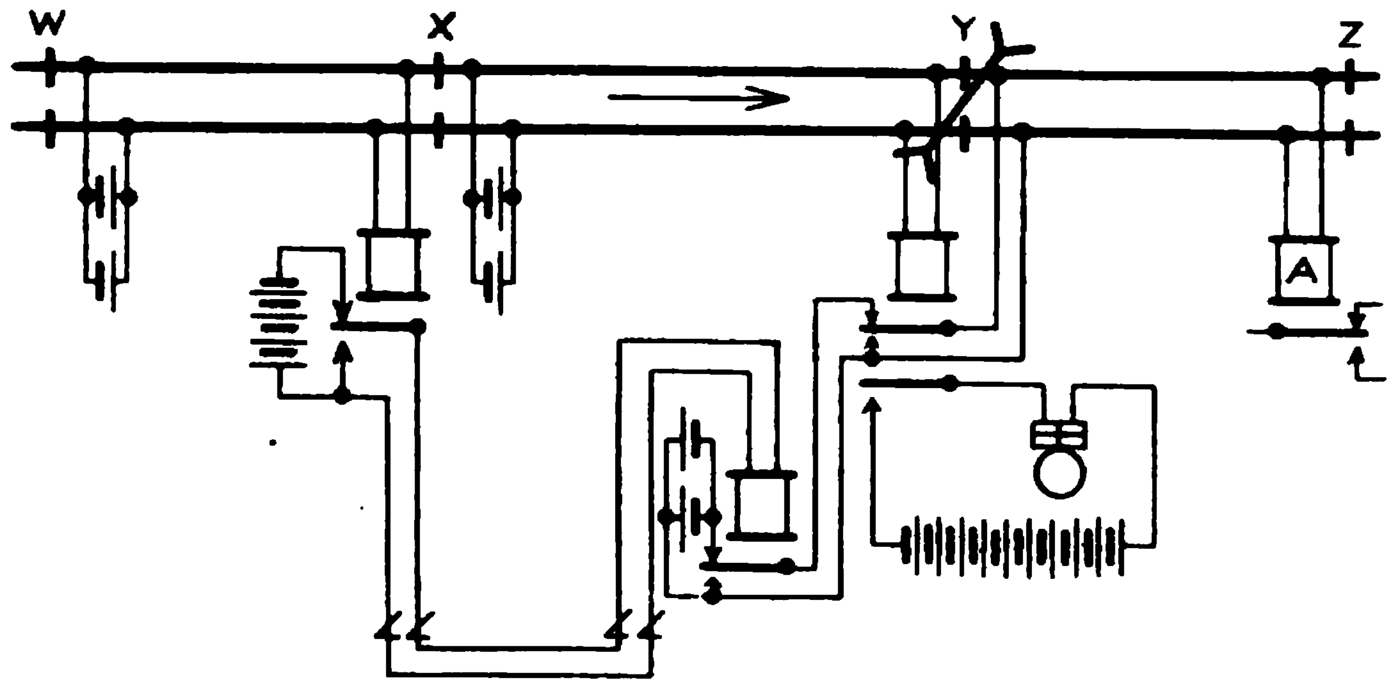


Fig. 61

141. *Clearing Relays.* Crossing alarms are sometimes operated in connection with other apparatus, by the use of *clearing relays,* as shown in Fig. 62. The clearing relay A (which may be either an ordinary 16-ohm relay, or a compound 16—16 or 24—24, relay) controls the alarm circuit, and relay B, the other apparatus.

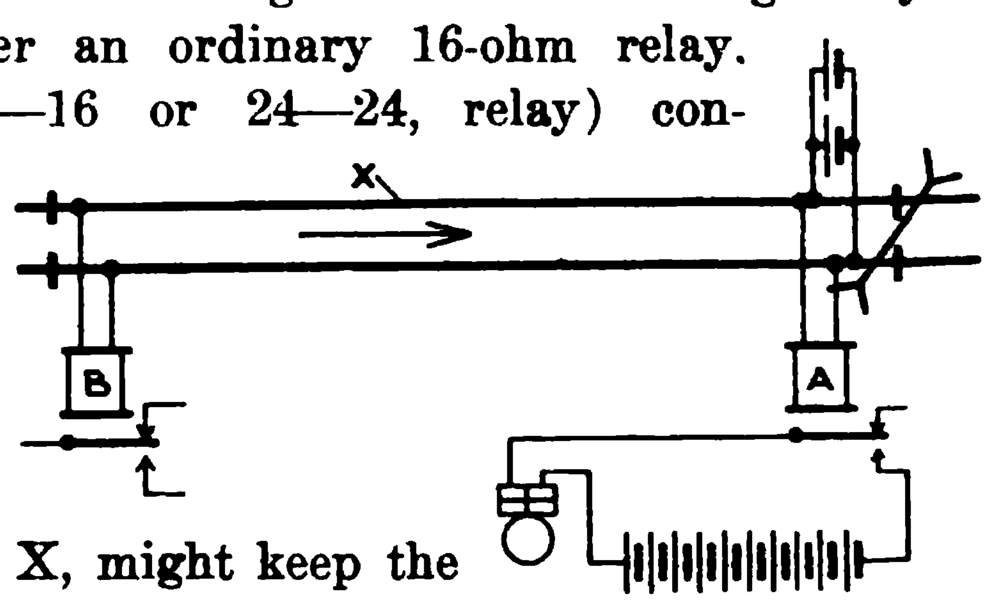


Fig. 62

With this arrangement a broken rail or defective bonding, for instance, at point X, might keep the bell from ringing until the train reached that point. However, as relay B would be likely to fail under such conditions, the consequent failure of the apparatus (frequently a signal) controlled by it, would draw attention to the trouble, and if a signal, the speed of trains would be reduced over the crossing, due to the signal assuming the danger position. Therefore the possibility of danger at the crossing on account of a broken rail or poor bonding is not considered very important.

142. *Stick Relays.* The term "stick relay" signifies an ordinary relay so connected into a circuit, that one of its front contacts closes a path for current through its own coils.

143. One method of arranging a stick relay is shown in Fig. 63, in which the relay is *normally de-energized.*

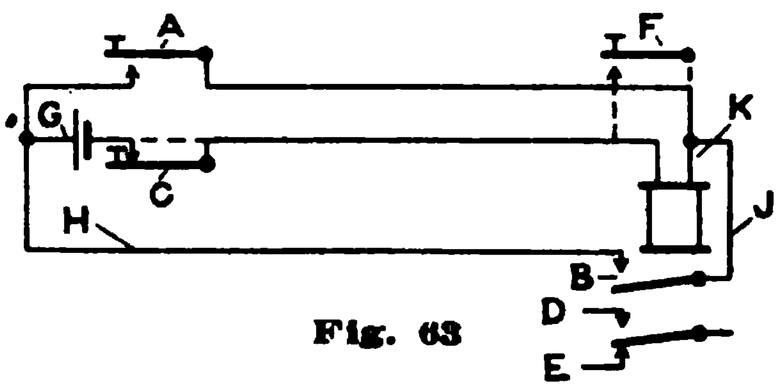


Fig. 63

When spring key A is closed the relay attracts its armature, thus completing a second path, known as the *stick circuit,* through contact B, and therefore keeping the relay energized after key A has been released, and until key C is depressed, thus cutting off all current from the relay.

The circuits controlled by the stick relay are carried through additional front or back contacts, as D or E.

144. In some instances a *normally open* key F, is employed in place of a normally closed key C. As will be seen this key when depressed, shunts the coils of the relay instead of breaking the stick circuit. In cases where the leads to key F are of some length and therefore have appreciable resistance, the relay may retain its armature when this key is closed, making good contact. This is especially noticeable when the internal resistance of the battery and the resistance of the wiring for the stick circuit is low, which when key F is closed, permits considerable current to flow. To overcome this suitable resistance may be inserted in the stick circuit.

When it is desired to release the relay from different points, two keys may be employed, being connected in series or in shunt as required.

145. In some cases the stick relay is kept *normally energized,* the arrangement being the same as that shown in Fig. 63, except that the operation is *reversed,* that is, instead of first closing key A to energize the relay and then de-energizing it with key C, the relay (being normally energized) is first de-energized with this key and then energized with key A.

146. The position of key C is varied to suit the conditions under which it is used; in fact, it may be placed in wires G, H, J or K, as at any of these points it will, when opened, break the stick circuit.

Relay contacts or other circuit closing devices, are very frequently employed in stick relay circuits, instead of spring keys.

147. *Tripping Circuits.* A method of using a stick relay for operating a crossing alarm is illustrated in Fig. 64. Ap-

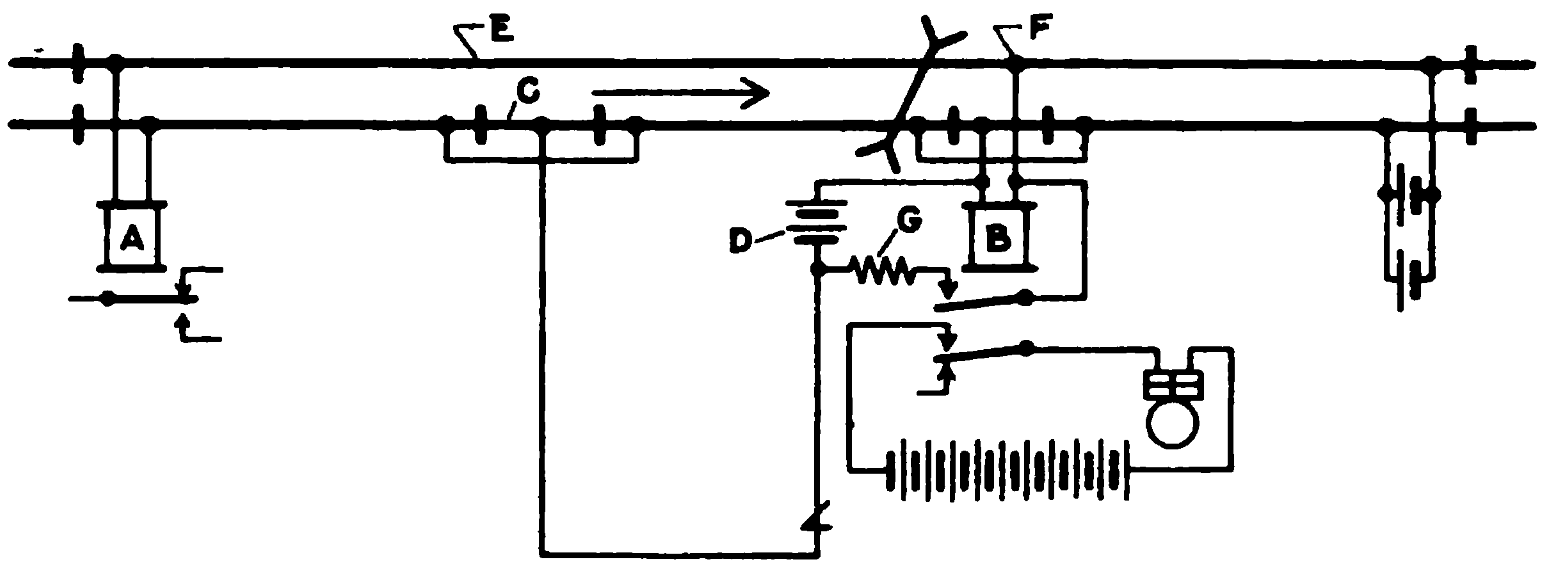


Fig. 64

paratus foreign to the alarm is controlled by relay A, into whose circuit is inserted two cut-outs, about one rail or less in length, for the control of the stick relay B.

148. When the train passes onto cut-out rail C, relay B is energized by current from battery D, flowing over the line to rail C. through the wheels and axles to the opposite rail (which acts as a common conductor for the two circuits between points E to F), and from point F, through the relay back to the battery. When the relay is thus picked up it closes the stick circuit through its upper contact finger and the bell circuit through its lower contact finger. As the train passes over the cut-out rail at the crossing, it shunts the current out of the stick relay, causing it to drop and open the bell circuit.

149. If gravity cells are used in battery D, resistance G, may generally be omitted, this resistance being used with batteries of low internal resistance, to avoid the improper energization of the stick relay, due to an excessive flow of current when the relay is shunted by wheels on the cut-out rail at the crossing.* Resistance G should be about equal to the line resistance, for if the battery provides sufficient current to pick up the relay through the line, it will of course, provide suf-

*See Art. 144.

ficient current to hold it up through a resistance of the same value.

150. It will be noted that the bell does not continue to ring until the rear end of the train reaches the crossing, as in the case of arrangements heretofore described, but stops when the first pair of wheels reaches the cut-out rail at the crossing.

151. With the arrangement shown in Fig. 64, the alarm is controlled entirely by *normally open circuits;* that is, the circuits are *normally de-energized.* It is evident, therefore, that if any of them should become interrupted, for instance, by a battery failure, broken wire, high resistance, etc., there would be no indication of this fact, until the bell failed to ring upon the approach of a train. Of course, this feature is true of the *bell circuit* in other arrangements described, but the probabilities of a bad condition in the bell circuit are much less than in the line circuit, in which the wire is constantly under strain. On this account, some engineers do not favor this arrangement. It is apparent that in such circuits lightning arresters should not contain fuses.*

Other methods employed for operating alarms by tripping circuits, are described in Art. 170.

152. Track Instrument Control: When track instruments are used to control automatic alarms on double track, it is customary to employ two instruments for each track, one being used to *start* the alarm operating, known as the *starter,* and the other, to *stop* it, known as the *stopper.* The *starter* is located at the point where it is desired that a train start the bell ringing, and the *stopper* at the crossing, preferably just in advance of it.

153. An arrangement of circuits for use with such instruments, employing two *normally open stick relays,* one for each track, is illustrated in Fig. 65. As will be seen the contacts in the starters are *normally open,* and those in the stoppers, *normally closed.*

*Compare with Art. 101.

154. When an east-bound train passes over starter A, it closes its contact and thus completes a circuit for relay B as

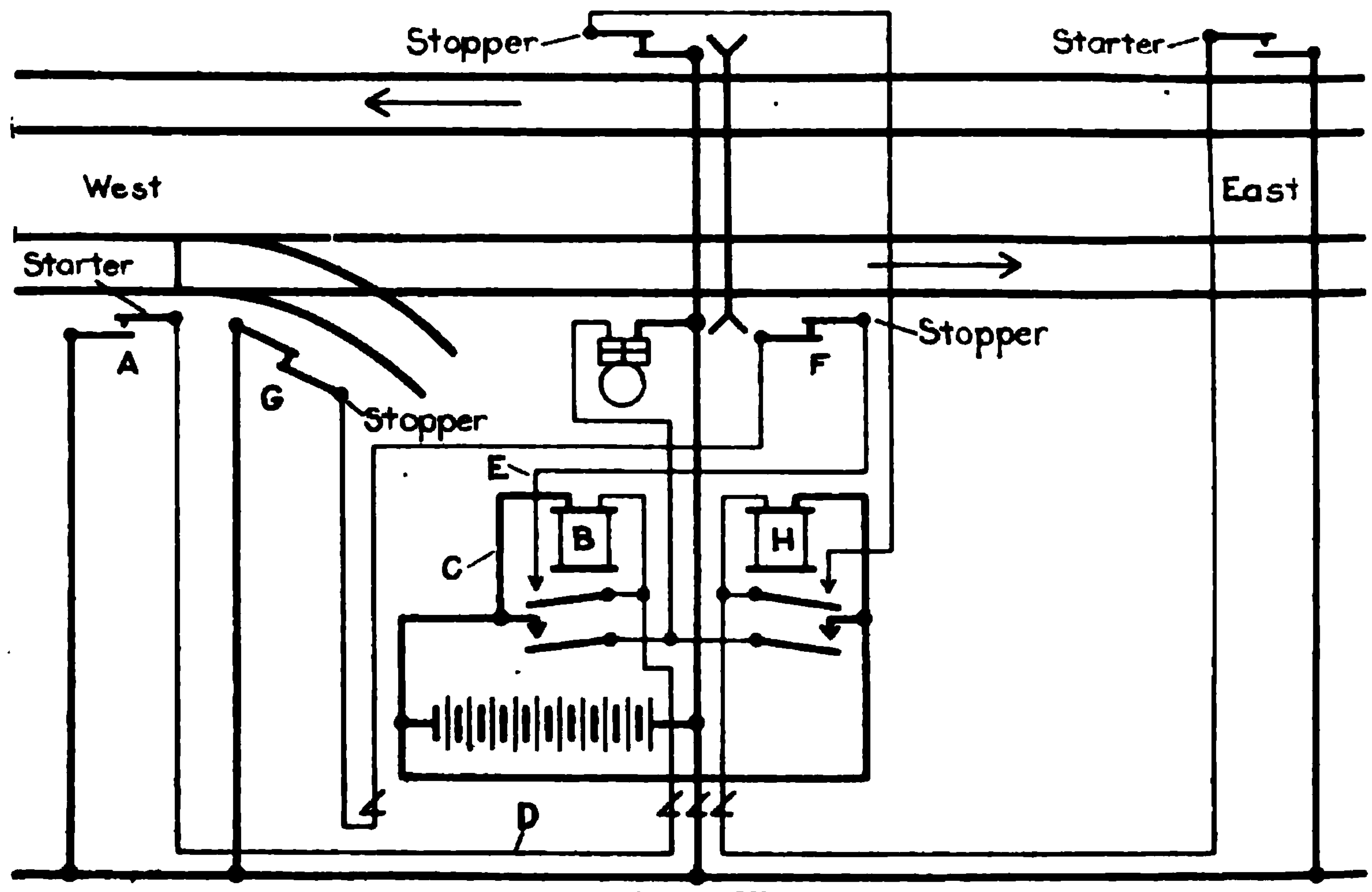


Fig. 65

follows: From the battery, through wire C, coil of relay B, line D, instrument A, and back to the battery. This causes the relay to pick up its armature, completing the bell circuit through its lower contact finger, and through its upper contact finger, the stick circuit, as follows: from the battery, through wire C, coil and upper contact finger of relay B, wire E, instruments F and G, and back to the battery. Therefore, although the line circuit through wire D, will be open after the train has passed instrument A, relay B will remain energized and the bell will continue to ring, until the train operates track instrument F or G, thus opening its contact and consequently breaking the stick circuit.

Stick relay H operates in a similar manner for west-bound trains.

155. The purpose of the additional stopper G, is to stop the alarm in case an approaching train, after operating starter A, should enter the siding instead of proceeding over the crossing.

156. It will be observed that the battery which feeds the line circuits (and also the bell circuit) is at the *same* end of the line as the relays.* This arrangement is desirable in this case.

*Compare with Art. 108.

as the line circuit is normally open instead of normally closed, and therefore crossed wires would produce the same effect as is produced by closing the starting instruments, that is, the bell would ring continuously, which would be safer than *preventing* it from ringing, as would probably happen in the case of crossed wires, if the batteries for these relays were located at the starting instruments.

157. As will be seen, no lightning arresters are provided between the line and the track instruments. This represents common practice, although they may be used if desired.

The return wire for the line circuits, is illustrated as being used *in common* with other circuits (not shown). Of course, if desired, a *separate* return wire may be used.

158. An arrangement of *normally closed line circuits,* employing track instruments, is illustrated in Fig. 66, the normal

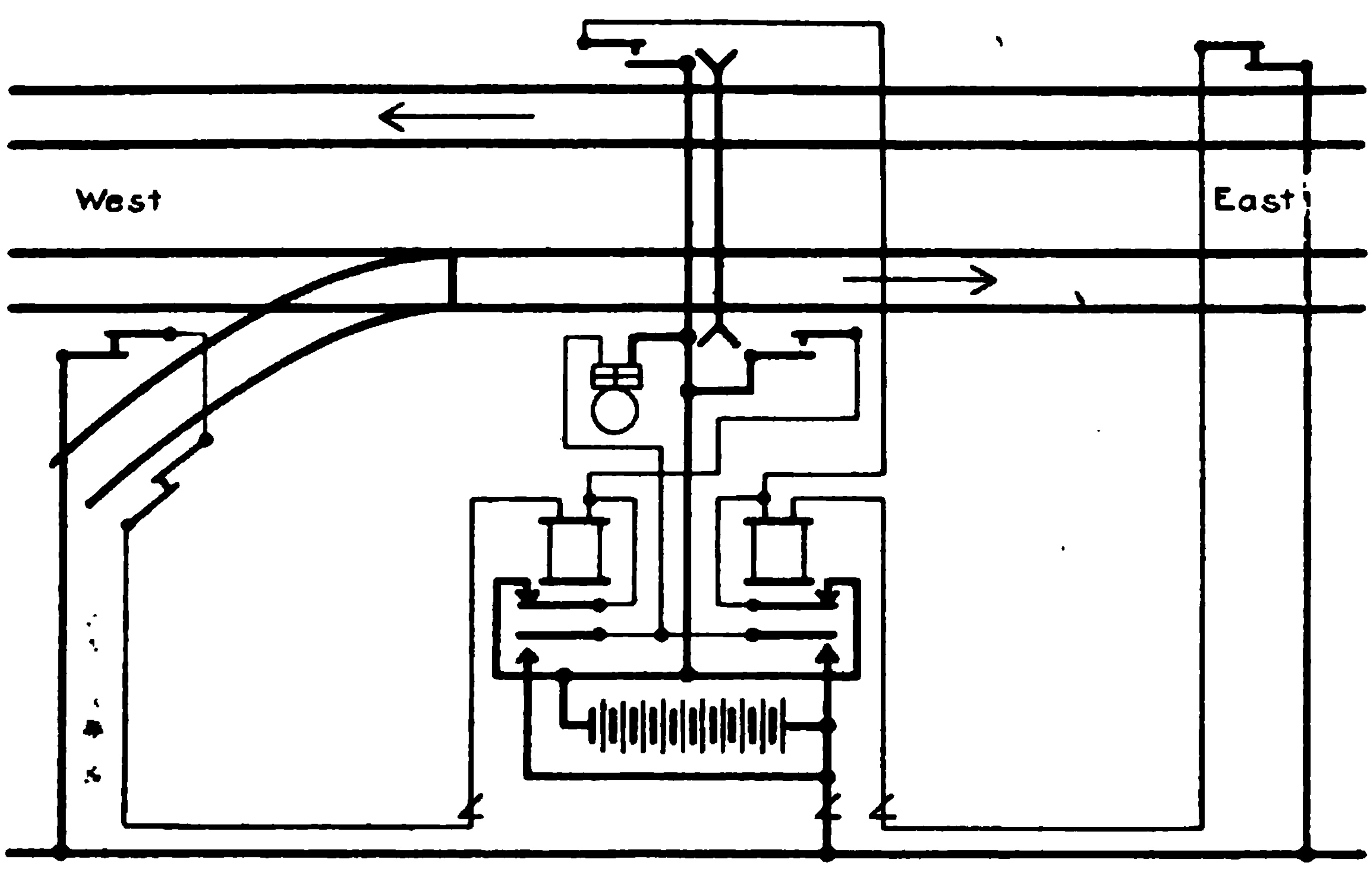


Fig. 66

position of the track instruments and stick relays, being the *reverse* to that shown in Fig. 65, and the bell circuit being controlled through *back* instead of *front* contacts.

159. As in this case, the *starters* form part of the *stick circuits,* a train passing over one of them will de-energize its stick

relay, thus causing the bell to ring until this relay is again energized by the train passing over the *stopper*.

As will be observed an additional starter is provided on the branch which joins the east-bound main track, thus an approaching train on the branch as well as one on the main line will start the alarm. If this were an ordinary siding instead of a branch, and it was desired to use the additional starter, it would be placed between the fouling point and the switch so as not to be operated by a train moving on the siding unless it was coming out onto the main track. If required, additional starters may of course be employed with any of the circuit arrangements here shown, being connected in multiple when the starter circuit is normally open and in series, as shown, when normally closed.

160. Protection against broken wires on the line circuits is of course, provided in Fig. 66, but not against crossed line wires.

If it is desired to employ normally closed circuits and also guard against dangerous failures from crossed wires, separate

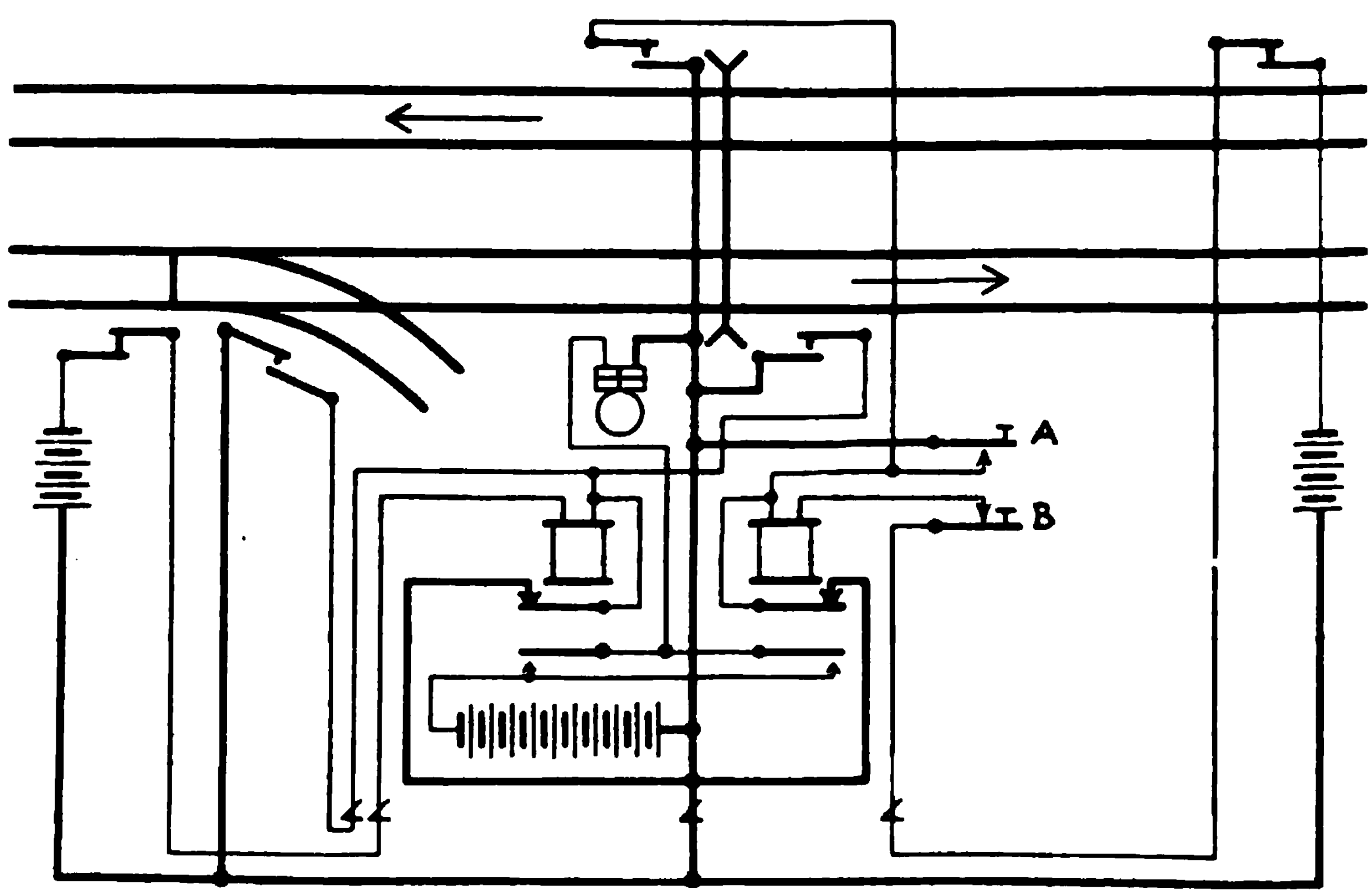


Fig. 67

batteries may be provided for the line circuits, as shown in Fig. 67.

It will be observed that an additional stopper is used at the siding and in this connection it should be noted that if the stopper at the crossing is normally open, the siding stopper is connected *in multiple,* but if normally closed, as in Fig. 65, it is connected *in series.*

In this case, the return for the bell circuit is carried on the common wire, being so arranged to save wire. Of course, the saving of wire depends largely upon the location of the relays, batteries, etc., and therefore, in many instances, it is possible to keep the return wire from the bell to the battery, separate from the other circuits without the use of much additional wire, which is of course a better arrangement.

161. The circuits shown in Fig. 68 are for use with the type of interlocking relay known as a *double circuit instrument.**

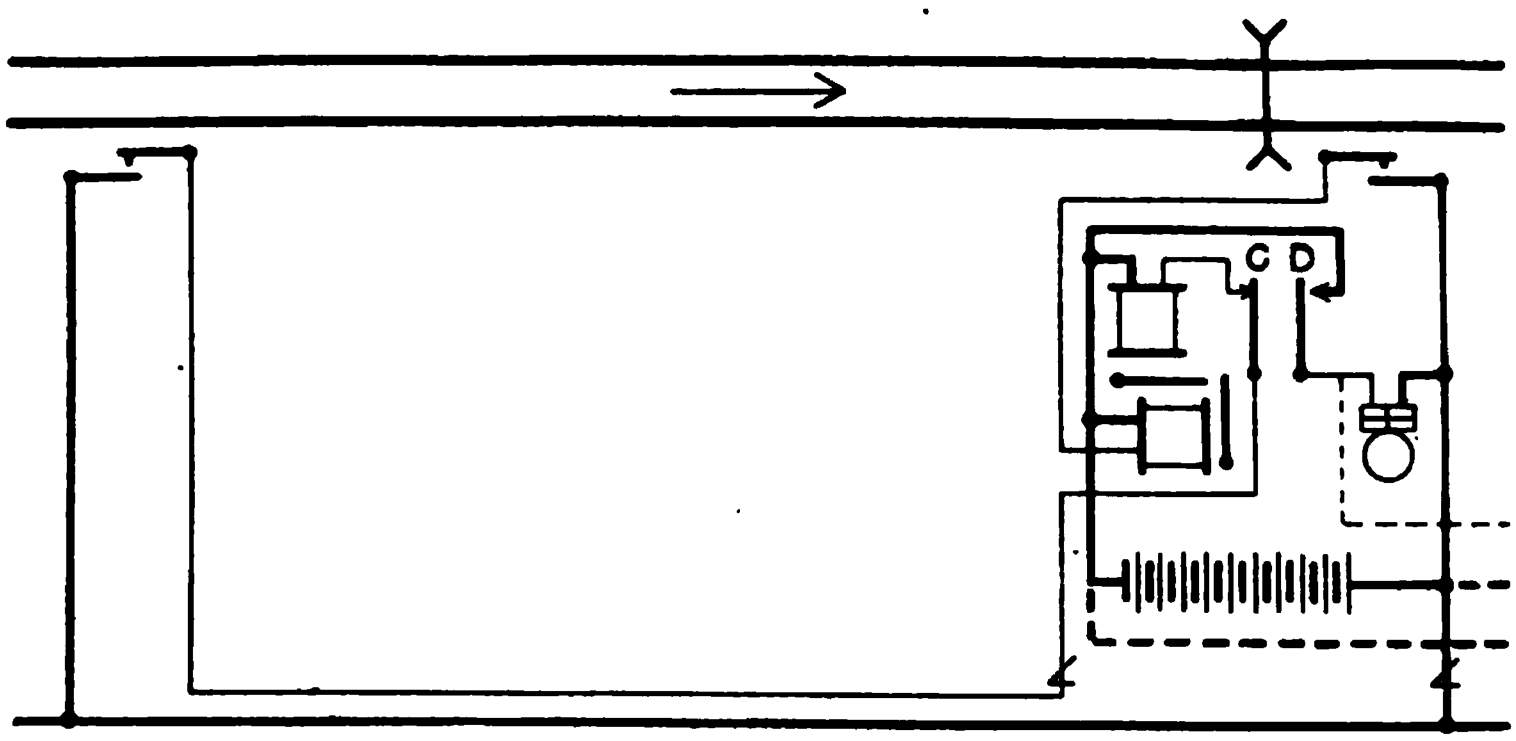


Fig. 68

The normal position of the instrument in this case is *locked;* that is, the vertical armature is held close to its magnets by the upper armature, and the retractile spring is compressed. All circuits are normally open, the upper magnet being energized when a train operates the starter. As soon as this magnet picks up its armature, it releases the vertical armature and allows the retractile spring to reverse the positions of the contacts. When contact C opens it breaks the line circuit and thus the entire energy of the battery is allowed to work on the bell, the circuit of which is closed by contact D. When the

*Described in D. C. Relays.

train reaches the stopper and closes its contact, the lower magnet is energized and its armature drawn up, which action restores the contacts to their normal position, thus stopping the bell, and permitting the upper armature to again lock the lower one.

The apparatus is duplicated for the other track (not shown), using the wiring indicated by dotted lines.

162. Time Circuit Controllers: An alarm circuit employing the *time circuit breaker*, Figs. 29-31, operated by a track instrument, is illustrated in Fig. 69. It will be observed that the track instrument takes the place of the key shown in Fig. 30, so that when it is closed the operation of the time circuit breaker is started, immediately closing the bell circuit and keeping it closed during its operation.

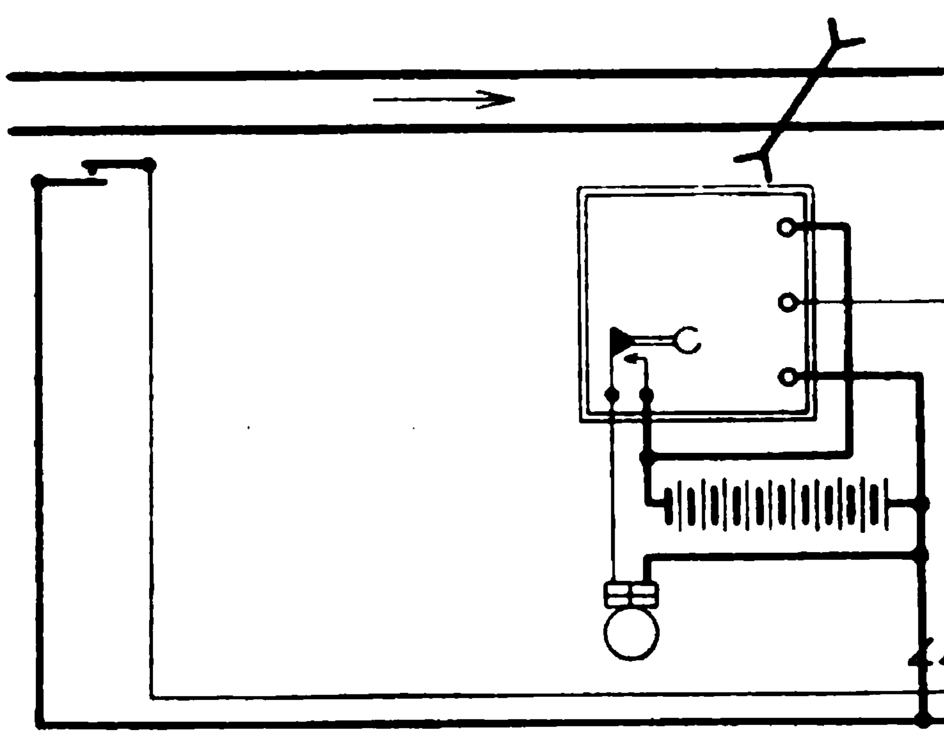


Fig. 69

163. A similar arrangement in which a separate battery is provided for the time circuit breaker, is shown in Fig. 70. This is considered a somewhat better scheme, as the bells are usually constructed to operate on a higher voltage than the time circuit breaker.

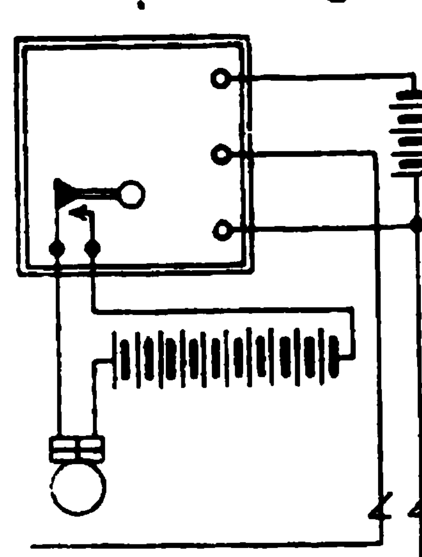


Fig. 70

Another reason for the use of two batteries is the fact that with the single battery arrangement, if as the bell armature vibrates, the bell circuit and the path through the coils of the time circuit breaker close at the same time, as is likely to occur quite often, the current through each, with batteries having high internal resistance, is reduced, probably affecting their operation.

164. At points where the speed of trains varies considerably with a consequent variation in the time required for trains to reach the crossing, after they have passed the starter, the arrangement just described is not always satisfactory, as the alarm cannot be timed to cover all conditions properly. For instance, if the time circuit breaker is set so as to stop the alarm in the time required for the fast trains to reach the crossing, it is evidently too short for the slower ones and if lengthened for them, it continues unnecessarily after the fast trains have passed the crossing, which is undesirable, as a person on the highway will wait, expecting a train on the other track.

165. In order to overcome such difficulties the time circuit breaker may be arranged to be controlled by two track instruments, a starter and a stopper, as shown in Fig. 71. This

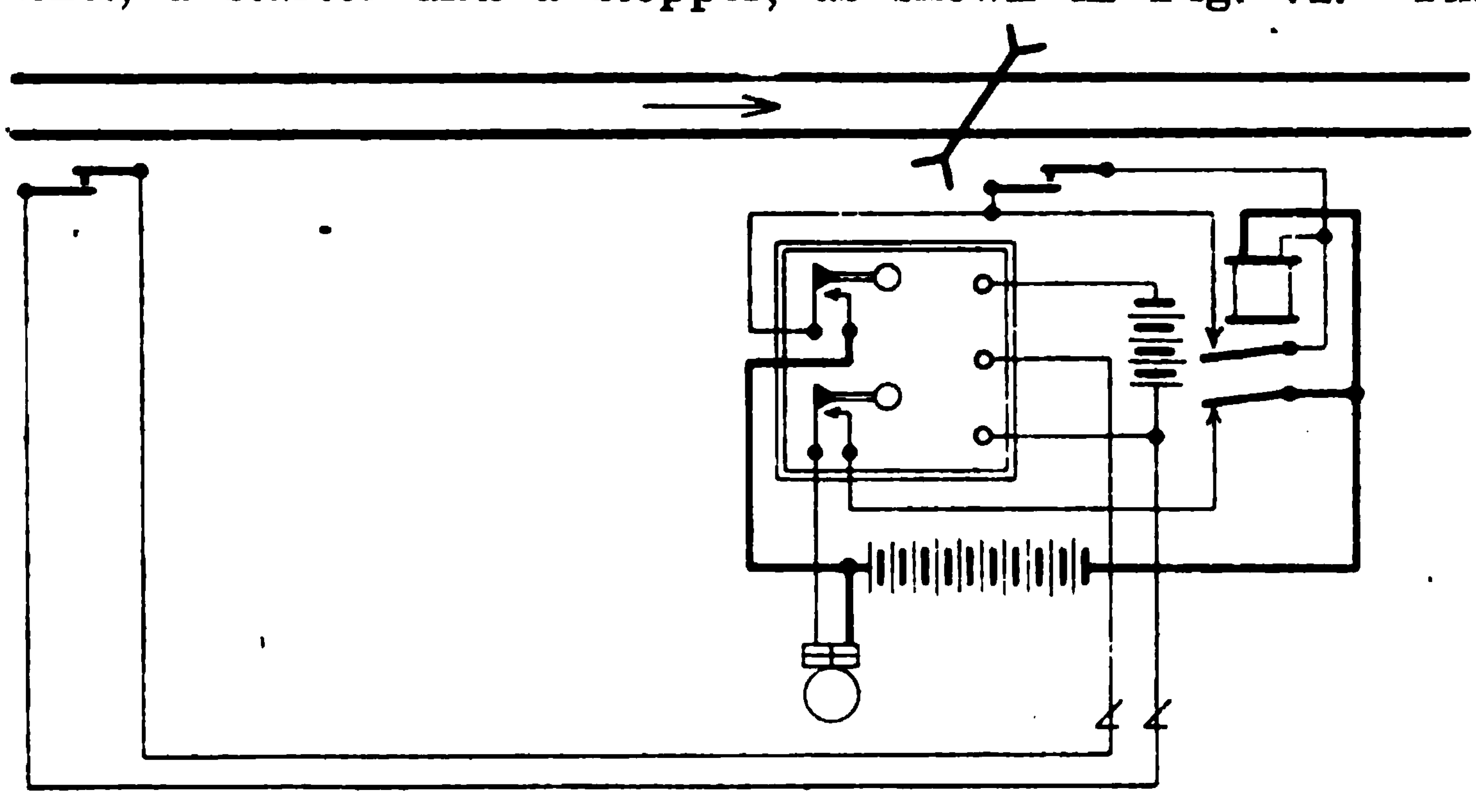


Fig. 71

provides for the cutting out of the bell by a stick relay actuated by the stopper, in case a train reaches the crossing before the time circuit breaker has completed its movement.

166. When the time circuit breaker is put in operation by the starter, it closes the bell circuit in the usual manner, and at the same time, closes another contact, which allows the stick relay to be energized, if the stopper is operated before the time circuit breaker has completed its movement. As the bell circuit is carried through a back contact on the stick relay,

it is broken when this relay is energized; the time circuit breaker, however, continues to operate until it has completed its movement, when it breaks the circuit of the stick relay, restoring all parts to their normal position.

The time circuit breaker is set to give the longest alarm that will be required and thus a satisfactory alarm is provided without false operation.

167. As indicated in the illustration separate batteries are provided for the time circuit breaker and the bell, but if desired one battery may be employed, as in Fig. 69.

168. Circuits employed with the *time element,* Fig. 33, are illustrated in Fig. 72, arranged for use on an electric railway.

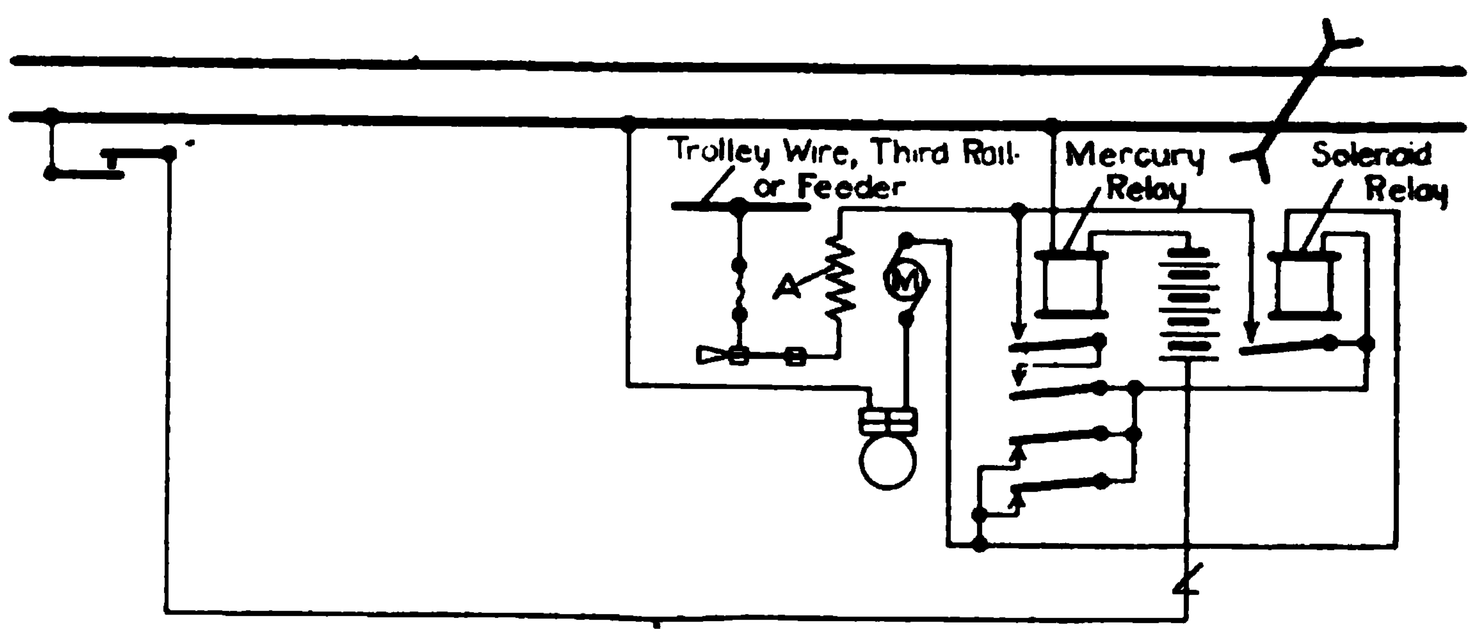


Fig. 72

The two lower contracts on the mercury relay are those operated by the ratchet device in conjunction with the motor. The mercury relay only is supplied with current from the battery whose circuit uses the rail as one conductor. The solenoid relay, motor and bell are operated by propulsion current, the voltage being cut down by inserting a suitable resistance A, in their circuit.

169. By a study of the circuits for alarms operated by track instruments and time circuit controllers it will be seen that test keys cannot be satisfactorily applied, because they would not indicate the condition of the track instruments. Therefore if a test is to be obtained it is necessary to observe the operation of the alarm when trains are approaching the crossing,

noting that it operates properly for trains on all possible routes.

170. Tripping track circuits, either normally open or normally closed, may be used with any of the arrangements shown in Figs. 65-72, instead of the track instruments.

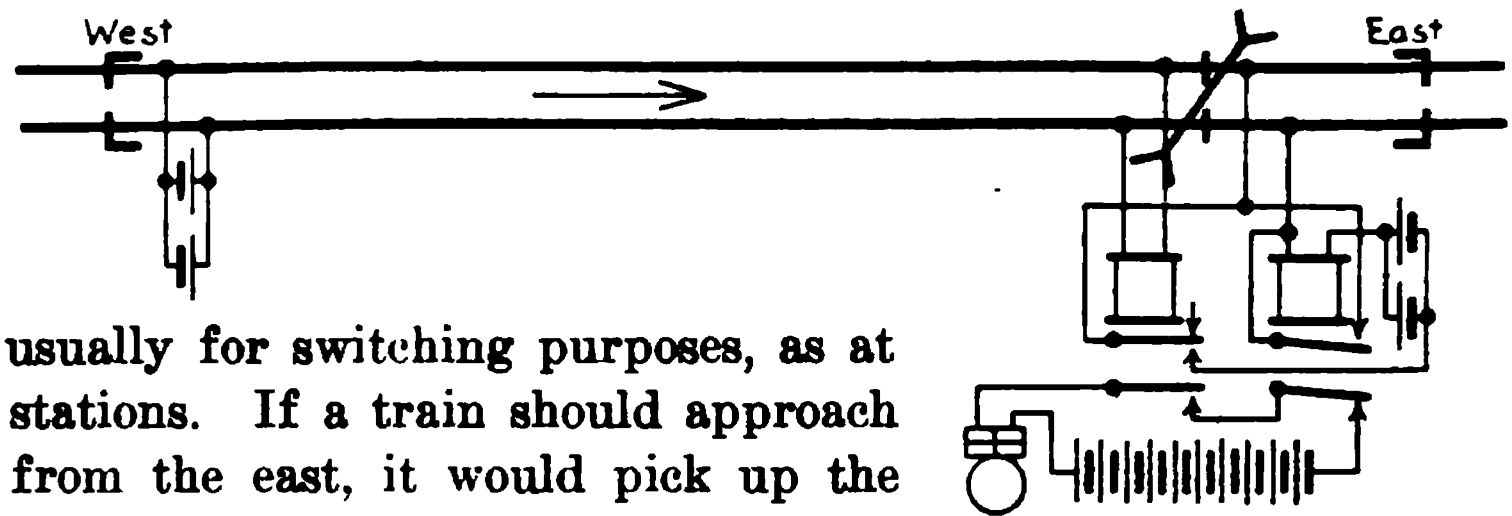
Normally closed circuits are in most cases, safer for *starting* the bell, as in case of a failure of such a track circuit, the bell will ring, whereas when normally open circuits are used such a failure will result in no indication being given by the bell, when a train passes over the circuit. However, normally open track circuits usually operate more quickly than the normally closed, making it necessary in the case of the latter, to have a slightly greater length of rail, which is sometimes undesirable, as for instance, where cut-outs (Fig. 64) are used for the tripping circuits.

Normally open track circuits are generally considered the most satisfactory for *stopping* the bell, as a failure of such circuits under these conditions, will, after the bell has started to operate, cause it to ring continuously, whereas the failure of a normally closed circuit under like conditions will either prevent the bell from starting to operate, or stop it before the train reaches the crossing.

171. Interrupting Devices: In some cases it is desired to leave cars standing on a track circuit which operates a crossing alarm, while part of the train passes over the crossing for the purpose of switching, etc. In order that the bell may not ring continuously, while the train is switching, the arrangement shown in Fig. 73, is sometimes used, a short normally open track circuit being installed at the crossing and its relay operated as a stick relay.

172. As will be seen, the bell stops ringing when the first pair of wheels reaches the normally open track circuit and will not again ring for this track until all the cars have passed off the normally closed track circuit, and this circuit is again occupied by a train moving in the normal direction of traffic.

173. The arrangement shown in Fig. 73, is also used to advantage at points where short *reverse* movements are made,

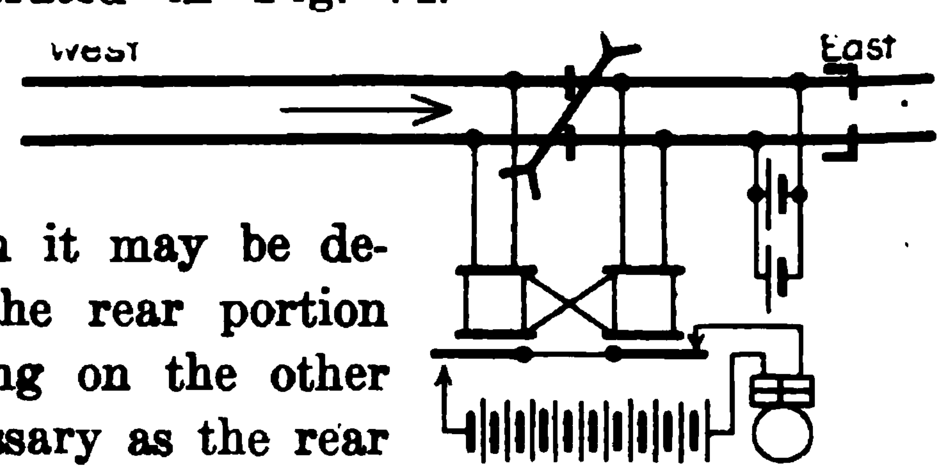


usually for switching purposes, as at stations. If a train should approach from the east, it would pick up the stick relay when passing from one

Fig. 73

circuit to the other and thus the bell would be kept from ringing while the train was working on the normally closed track circuit. As train movements at the crossing in such cases, are usually very slow and as it is often customary to have the crossing guarded by trainmen while such movements are being made, this arrangement is generally satisfactory.

174. An arrangement in which an *interlocking relay* is used for a purpose similar to that described in connection with Fig. 73, is illustrated in Fig. 74.



The circuit to the east of the crossing is made long enough to cover movements which it may be desired to make while the rear portion of the train is standing on the other circuit, this being necessary as the rear portion of the train would cause the

Fig. 74

bell to ring, if the forward portion moved east, clear of the circuit. In this respect, it should be noted that it differs from the arrangements shown in Fig. 73. It also differs from that arrangement in that a train which enters the circuit west of the crossing, before the train ahead has left the circuit east of the crossing, will ring the bell as soon as the first train has passed off the circuit, instead of failing to do so, as in Fig. 73. As the bell will not ring when a train is on the circuit east of the crossing, this should be made as short as possible in order that a proper alarm will be given for the train in the rear and

on this account this arrangement should not be used where switching movements are made at any great distance east of the crossing.

175. In the case of reverse movements the interlocking feature keeps the back contact from closing; therefore, the operation in such cases, is the same as described in connection with Fig. 73.

It should be observed that a failure of the track circuit to the east of the crossing, Fig. 74, will prevent the alarm from operating.

176. In case a switch, which is frequently used, occurs in the track circuit which operates a crossing alarm, a develop-

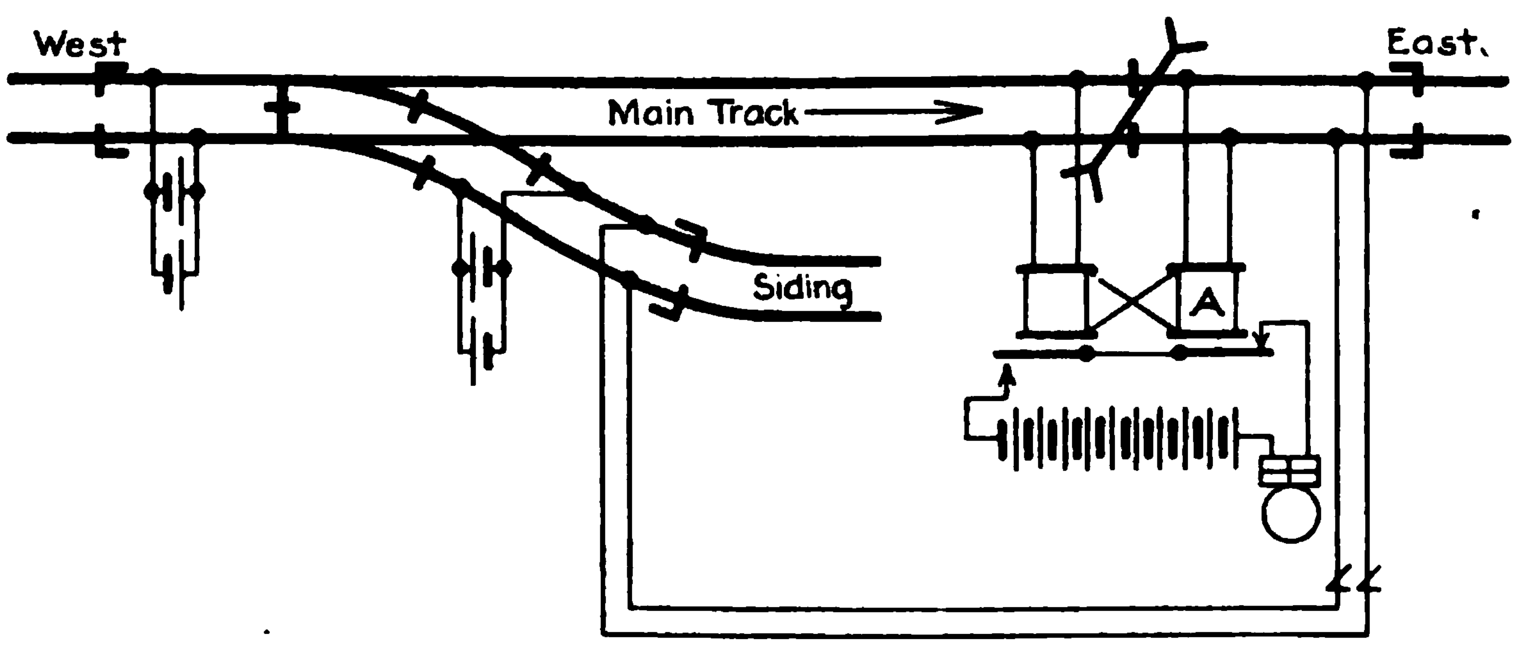


Fig. 75

ment of the circuit shown in Fig. 74, may be employed, as illustrated in Fig. 75. It will be seen that a train moving to or from the siding will keep the bell from giving a false alarm.

177. Where the conditions are such that the track circuit east of the crossing is unnecessary, it may be omitted, the line circuit being carried directly to relay coils A.

178. Carrying the track circuit on line wires (or in trunking) as shown in Fig. 75, while satisfactory for a few hundred feet, may, on account of the resistance of the wire, be found unsatisfactory, for longer distances.

In such cases, or in case it is not desired to use line wires, the arrangement shown in Fig. 76, may be employed. A *switch*

circuit controller, or *switch box*,* which is operated by the switch, is so arranged that when the switch is reversed, con-

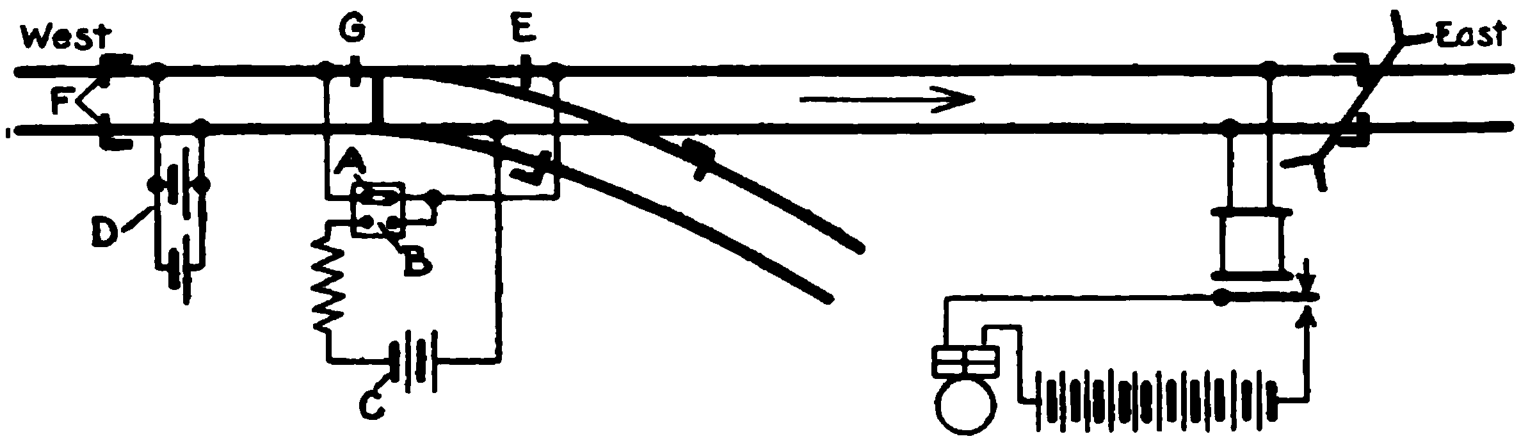


Fig. 76

tact A will be opened and contact B, closed. A cut-out is installed at the switch, the jumper being carried through the normally closed contact on the switch box, as shown. When the switch is opened current from battery C, feeds the relay, instead of that from battery D; thus under these conditions, the track circuit begins at joint E instead of joints F. Therefore when the switch is opened the relay will be energized by battery C, regardless of the presence of a train west of the switch, consequently a train entering or coming from the siding will not ring the bell.

The switch box is arranged to close one contact before breaking the other, so that the bell will not ring improperly while the switch is being reversed.

179. As battery C is on open circuit most of the time, it is considered most economical to use caustic soda or potash cells with the proper series resistance as shown.

If desired, insulated joint G may be omitted, by insulating the switch rods and cross rail.

180. The arrangement shown in Fig. 76, may be considered safer than that illustrated in Fig. 75, as a failure of the track circuit cannot keep the bell from ringing.

181. A test key employed at the crossing, Fig. 76, does not insure that the alarm will operate for a train west of the switch, as the switch box may be disconnected and left in the reverse position, thus shortening the alarm circuit to the

*A detailed description of switch boxes is given hereafter.

switch, and allowing the alarm to operate properly for the test key.

182. In some cases it is necessary to allow a train to stand on the track circuit which controls the crossing alarm, for instance to handle passengers or freight, during which time it is desired to stop the operation of the alarm.

An arrangement for accomplishing this is illustrated in Fig. 77, in which a stick relay is employed, being supplied with current by the bell battery and operated by a spring key. The key may be located at the crossing or at any other convenient point to be operated by trainmen, who also guard the crossing,* or it may be placed in the office of a station, to be operated by the station attendant.

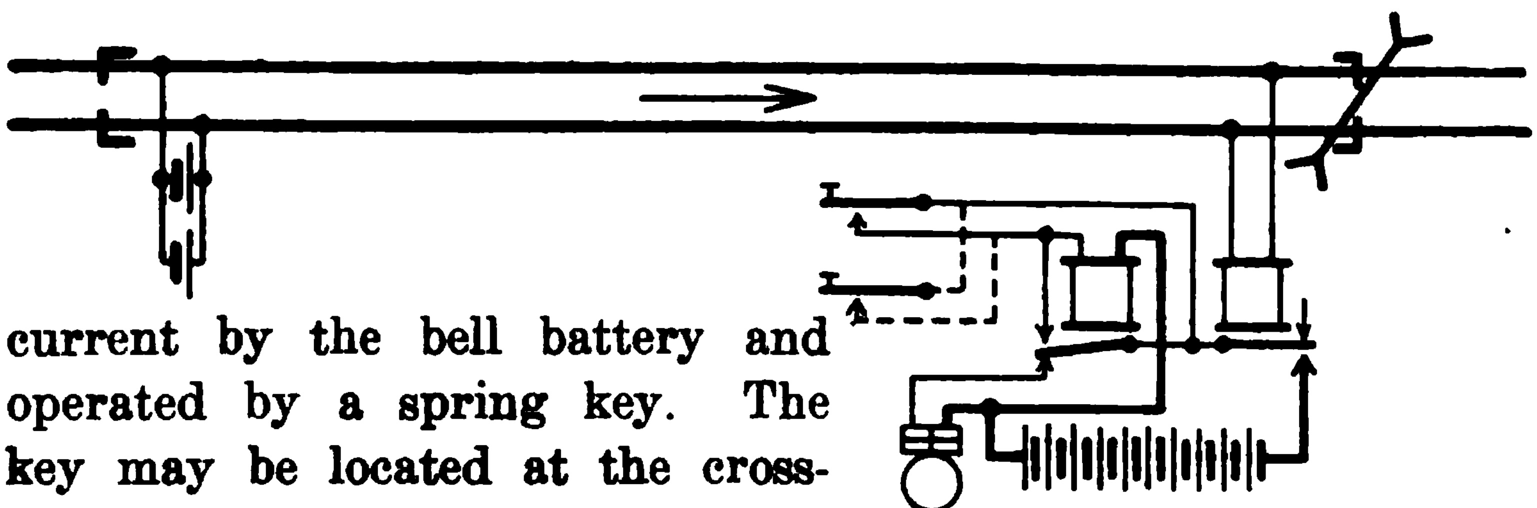


Fig. 77

183. If the key is closed while the track circuit is occupied, the stick relay will be energized, thereby stopping the alarm. When the key is released the stick relay remains energized, its armature being held up by current passing through the front contact of the stick relay and the back contact of the track relay. When the train passes off the track circuit, the stick circuit is broken by the track relay, which also breaks the bell circuit thus restoring all apparatus to its normal position.

184. It would not be advisable under these conditions, to use a cut-out switch in the alarm circuit to stop the operation of the alarm, in place of the interrupting keys, as it might be opened and then forgotten, producing a dangerous condition.

185. If the bell battery is used as shown, the resistance of the stick relay should of course, be high, but if a high resistance

*See Art. 173.

relay is not obtainable, one of low resistance may be used, arranged as shown in Fig. 78. This substitution may be made in similar arrangements described hereafter.

It will be noted in Fig. 77, that two or more keys may be provided, where it is desired to stop the operation of the alarm from different points.

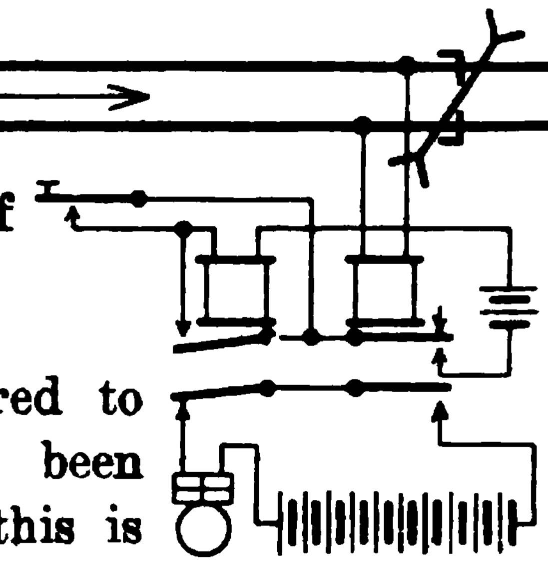


Fig. 78

186. In some cases a key is desired to again start the alarm, after it has been stopped. A means of accomplishing this is illustrated in Fig. 79, in which stopping and starting keys are provided at *two* different points. As will be seen, with the track occupied, either of the stopping keys A or B, when closed, will energize the stick relay and stop the alarm, and either of the starting keys C or D, when opened, will, owing to their being in series with the stick circuit, de-energize the stick relay and therefore will again start the alarm. If it is desired to have keys at only one point as A and C, it is evident that this can readily be arranged, in fact any combination of keys may be provided.

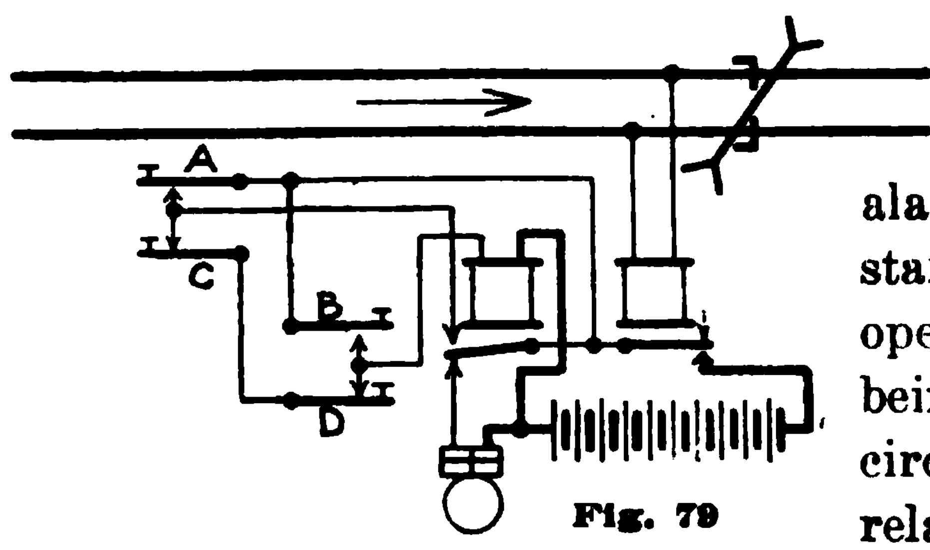


Fig. 79

187. In some instances, the alarm is so arranged that it will start automatically after it has been stopped, a method for doing this being shown in Fig. 80. A short normally closed track circuit is cut into the regular track circuit

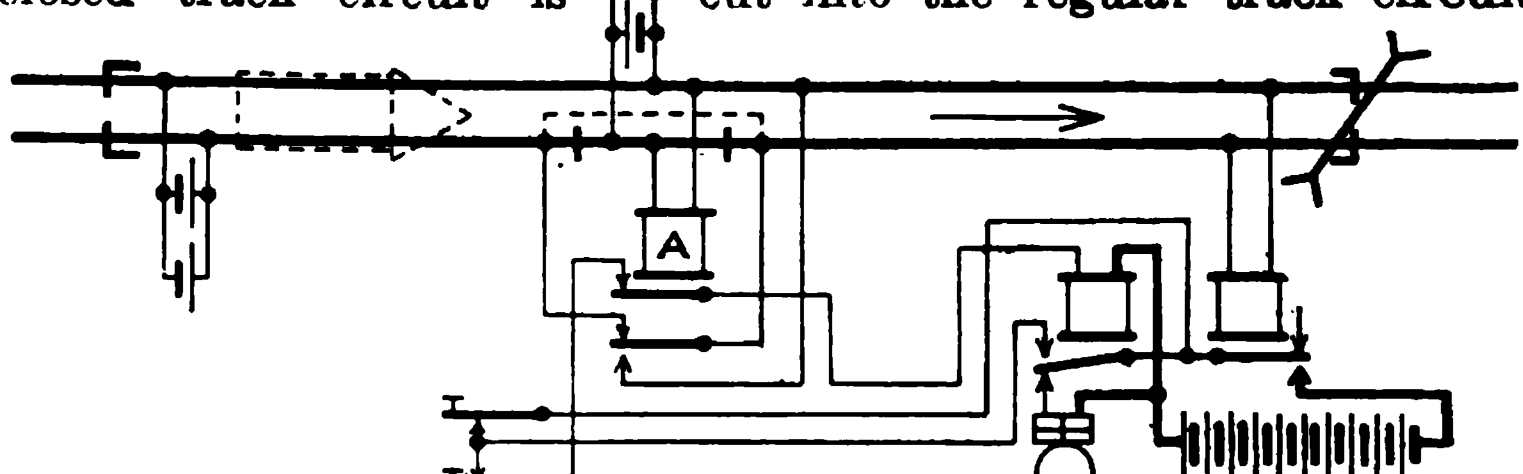


Fig. 80

just in advance of the point where the train is to stand (shown dotted).

188. After the bell has been stopped by closing the upper key, it may be started again by opening the lower key, or by the train shunting track relay A, either of which will open the stick circuit, causing the bell to ring.

189. As will be observed relay A when de-energized, breaks the jumper of the regular track circuit and also shunts its relay. If trouble from foreign current is to be guarded against, it is sometimes considered better to run the jumper as shown dotted, simply allowing relay A to shunt the other track relay through its back contact.

190. If desired a track instrument may be substituted for the short track circuit, one normally closed contact being provided to break the stick circuit when the instrument is operated.

191. Where *buzzers* are employed, to indicate the effect of the operation of the interrupting keys on the bell, the arrangement shown in Fig. 81, is generally used. As indicated the buzzer is in multiple with the bell and two contacts are required on the stick relay. In case the buzzer does not require the full voltage of the bell circuit, resistance as shown at A, is used.

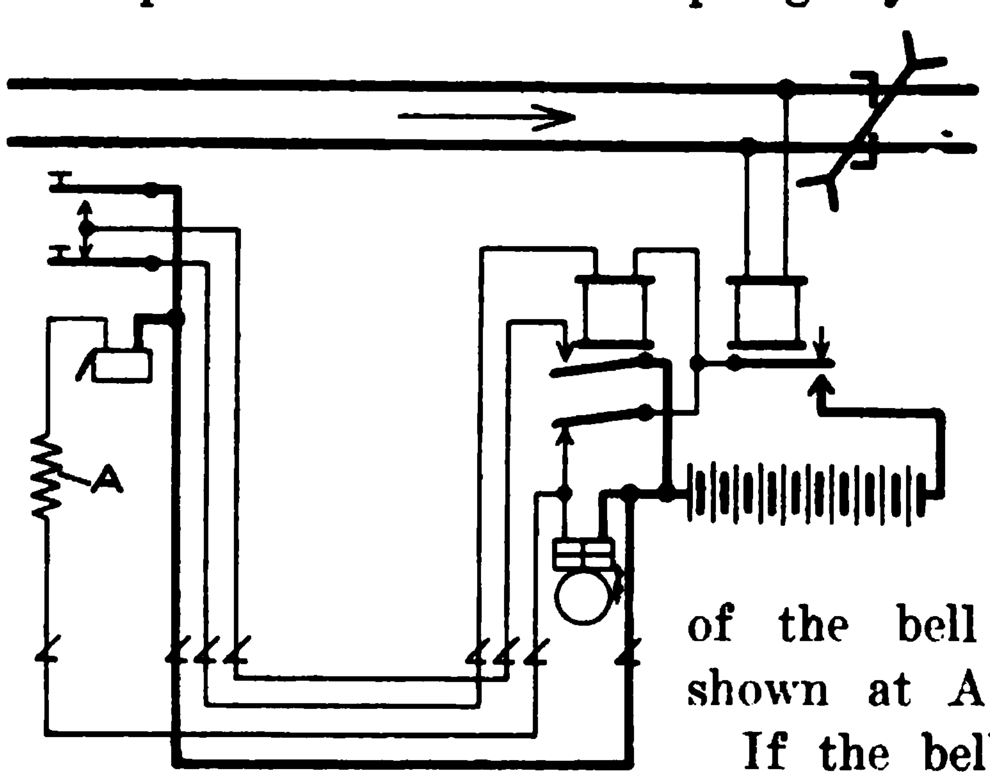


Fig. 81

If the bell circuit should be interrupted, as, for instance, by poor connection at the bell contact, the buzzer when connected as shown, will continue to operate properly. Therefore the action of the buzzer should not be taken as a test for the condition of the alarm.

It will be noted that lightning arresters are cut into the wires leading to the *keys*. It is usually considered unnecessary to so protect the *keys*, the arresters only being employed when the wires enter *buildings*, to protect them from fire. It is, of course, not advisable to use fuses in the circuits for normally open starting keys.

192. Where on account of the distance or for any other reason, it is not desired to run wires from the crossing to the point

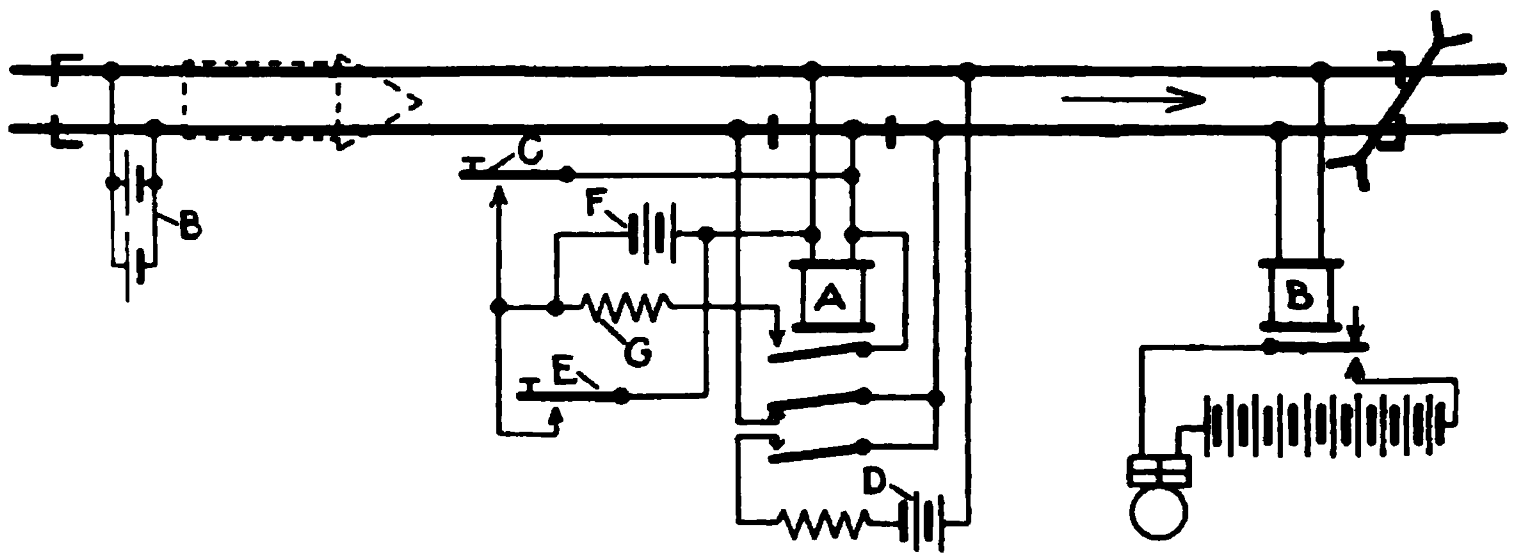


Fig. 82

where the train starts the bell after it has been stopped by the key, the arrangement shown in Fig. 82, may be employed.

193. It will be noted that the jumper of the regular track circuit is carried through a back contact on relay A, and that when a train enters the circuit, it shunts relay B, and consequently rings the bell. The operation of the bell may be stopped by closing key C, thus completing the circuit for stick relay A, which when energized completes the stick circuit through its upper front contact. When the stick relay is energized, the same effect is produced by its two lower contacts, as by the switch box contacts in Fig. 76 when the switch is reversed, battery D supplying current to relay B, energizing it and stopping the bell. When the bell is to be started again, either key E is closed, thus shunting the stick relay, or the same effect is produced by the train proceeding onto the short track circuit.

194. If there is a great length of wire between battery F and key E, the depressing of this key may not be effective in

shunting the relay on account of the resistance of this wire. In such cases, it may be desirable to insert resistance G, to offset that of the wire, or to use a normally closed key, cut in series with the stick circuit, so that when opened it will break this circuit instead of shunting it.

195. It should be observed that the interrupting arrangement, Fig. 82, differs from the others described, in that the cutting out key is effective whether a train is present on circuit B or not, and if after being operated for a train on that circuit (shown dotted) the train should back off or pass onto a siding, the apparatus would not be automatically restored to its normal position, but would require the operation of the starting key. Therefore, if this operation should be neglected, a fast train might approach and not operate the alarm until it reached the starting circuit, thus giving a short alarm and consequently producing a dangerous condition.

196. An application of the *time circuit breaker*, Figs. 29-31, for cutting out a crossing alarm, is illustrated in Fig. 83.

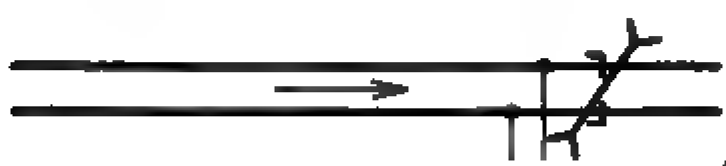


Fig. 83

It will be observed that when the track relay is de-energized, it starts the bell ringing and also starts the time circuit breaker operating. The arm which normally stands just above the ivory block, has to travel nearly a complete revolution before it closes the contact which picks up the stick relay. If the train is moving fast it passes off the track circuit and stops the bell in the ordinary way, before the time circuit breaker closes the stick relay circuit, and the time circuit breaker stops when it has completed one revolution. However, if the train is moving slowly or is stopped before it passes off the track circuit, the stick relay picks up and stops the bell, the time circuit breaker continuing to run as long as the track relay is de-energized. In this case,

when the track relay is energized due to the train passing off the circuit, it cuts off current from the stick relay and also current from binding post 2, so that the time circuit breaker stops when it reaches its normal position. In fact, all of the instruments automatically assume their normal position, after the track relay is energized.

197. Interrupting devices may, of course, be employed with alarms operated by track instruments, although, as the operation of the stopper breaks the bell circuit when the first pair of wheels reaches it, additional apparatus, as shown in Figs. 73-76, is unnecessary.

When it is desired to use stopping and starting keys they may be cut in, the same as additional track instruments would be; for instance, in Fig. 67, the stopping key would be normally open and arranged in multiple with the stopper as shown for the west-bound track at A, while the starting key would be normally closed and connected in series with the starter as shown at B.

Similar stopping and starting keys may also be arranged with the tripping circuits shown in Fig. 64.

198. Where interrupting devices are installed, care should be taken to so arrange them, that if the alarm is interrupted for one track, its operation for the other track will not be interfered with.

On double track, where there is considerable traffic in *both* directions on *each* track, the circuits for *single track arrangements* are sometimes employed on each track, so that the alarm will operate when trains approach the crossing from either direction.

199. Annunciators: When it is desired to operate an annunciator (bell or buzzer) to warn the flagman at highway crossings of the approach of trains, the arrangement illustrated in Fig. 84, is sometimes employed.

Short track circuits (long enough so as not to allow cars to span them, which would cause intermittent ringing) are in-

stalled at a certain distance from the crossing. When either of these circuits are occupied, the relay is closed, consequently ringing the bell at the cabin.

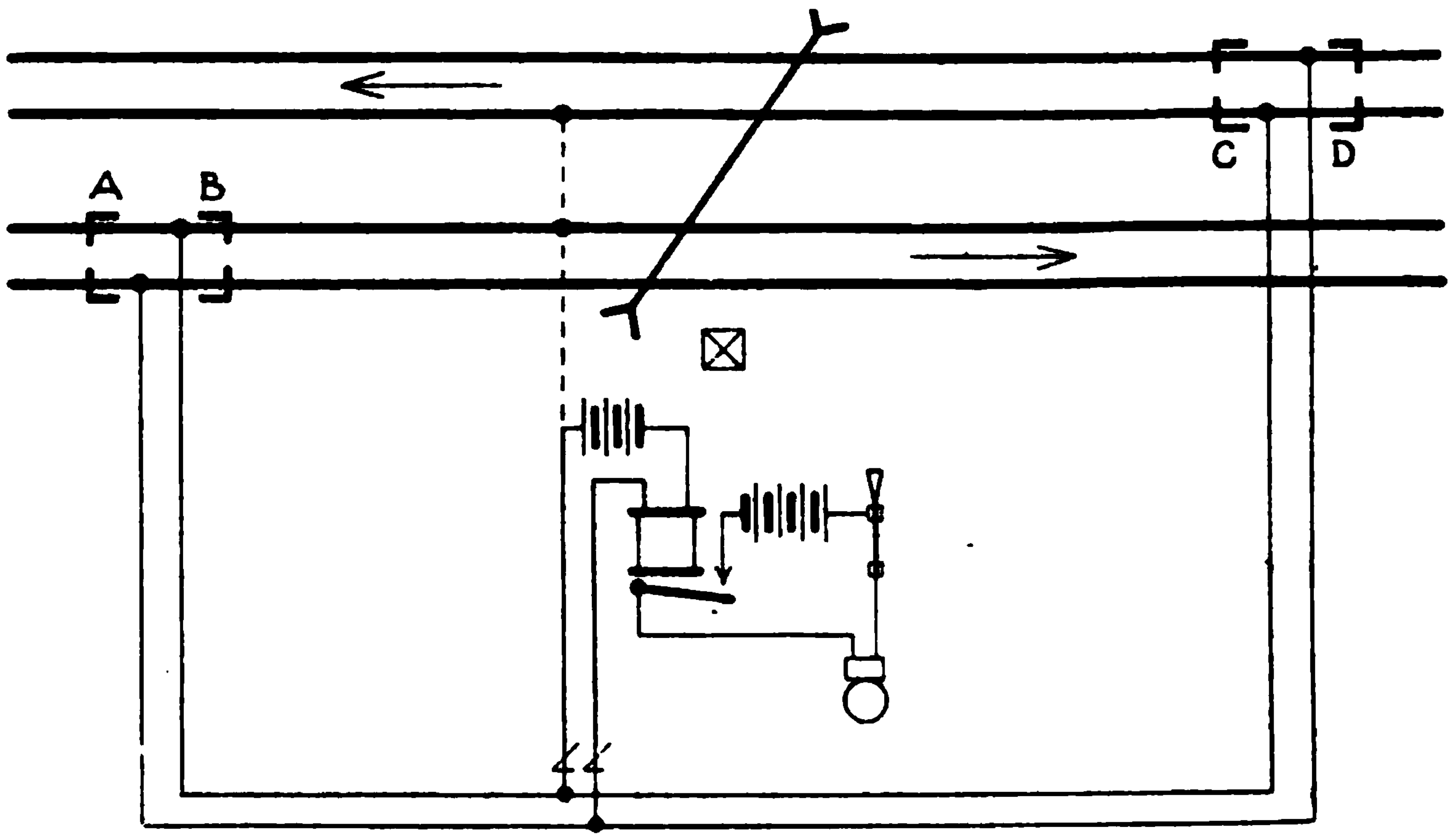


Fig. 84

200. In some instances single rail track circuits are used, insulated joints A, B, C and D being omitted, and in some cases the upper line wire also is omitted, the common rail of each track being bonded and connected to the battery as shown dotted.

201. The knife switch is provided in order to cut out the bell, if it gets out of order and rings continuously.

202. The arrangement shown in Fig. 84, or its variations, may be used where the ringing points are not more than 1,000 or 1,200 ft. from the crossing, but for greater distances the resistance of the line would usually interfere with the operation of the relay, as the voltage employed is necessarily low on account of the circuit being connected to the track, and therefore separate track circuits are provided, the arrangement illustrated in Fig. 85, being one method employed.

203. The track circuits are often arranged normally open as shown, but in some cases normally closed track circuits are

employed using the back instead of the front contact of the relay, which is of course, a safer arrangement.

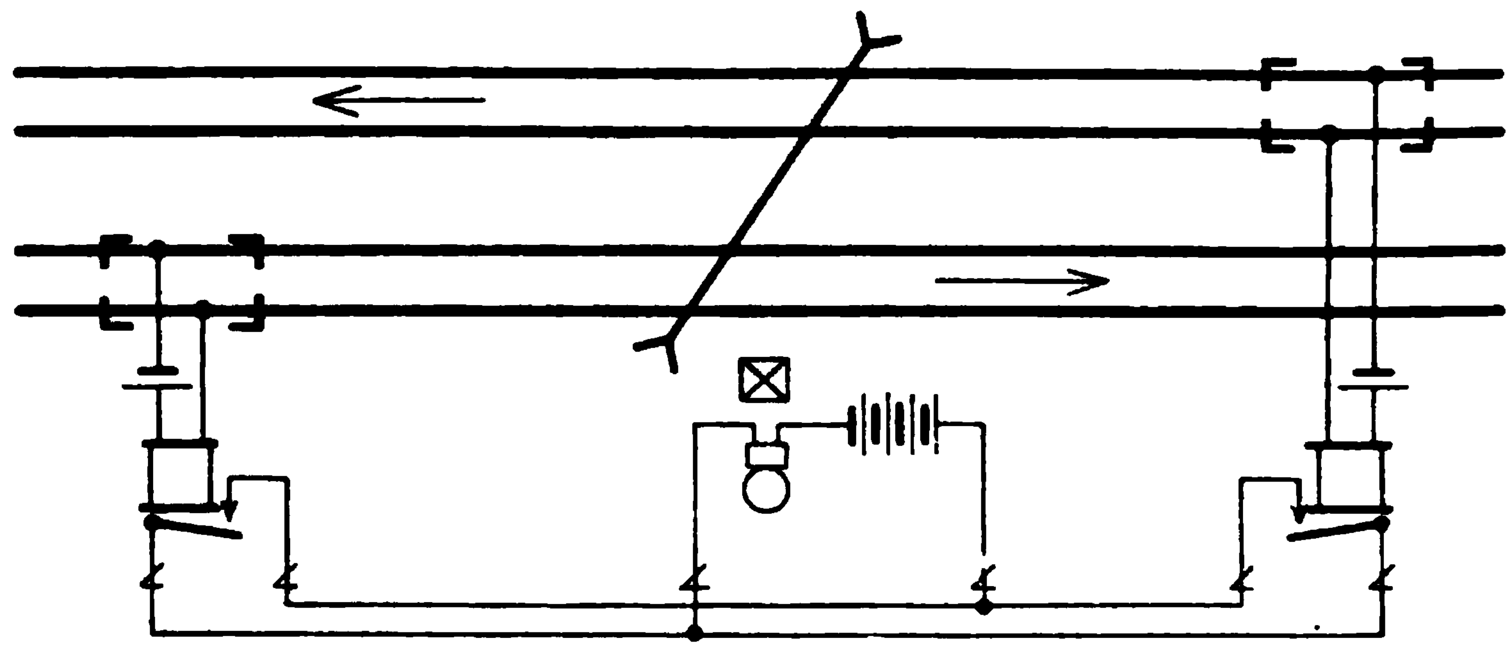


Fig. 85

204. On account of the resistance of the line wires it is considered desirable, in some instances, especially when a high resistance bell is not obtainable, to use a line relay as shown

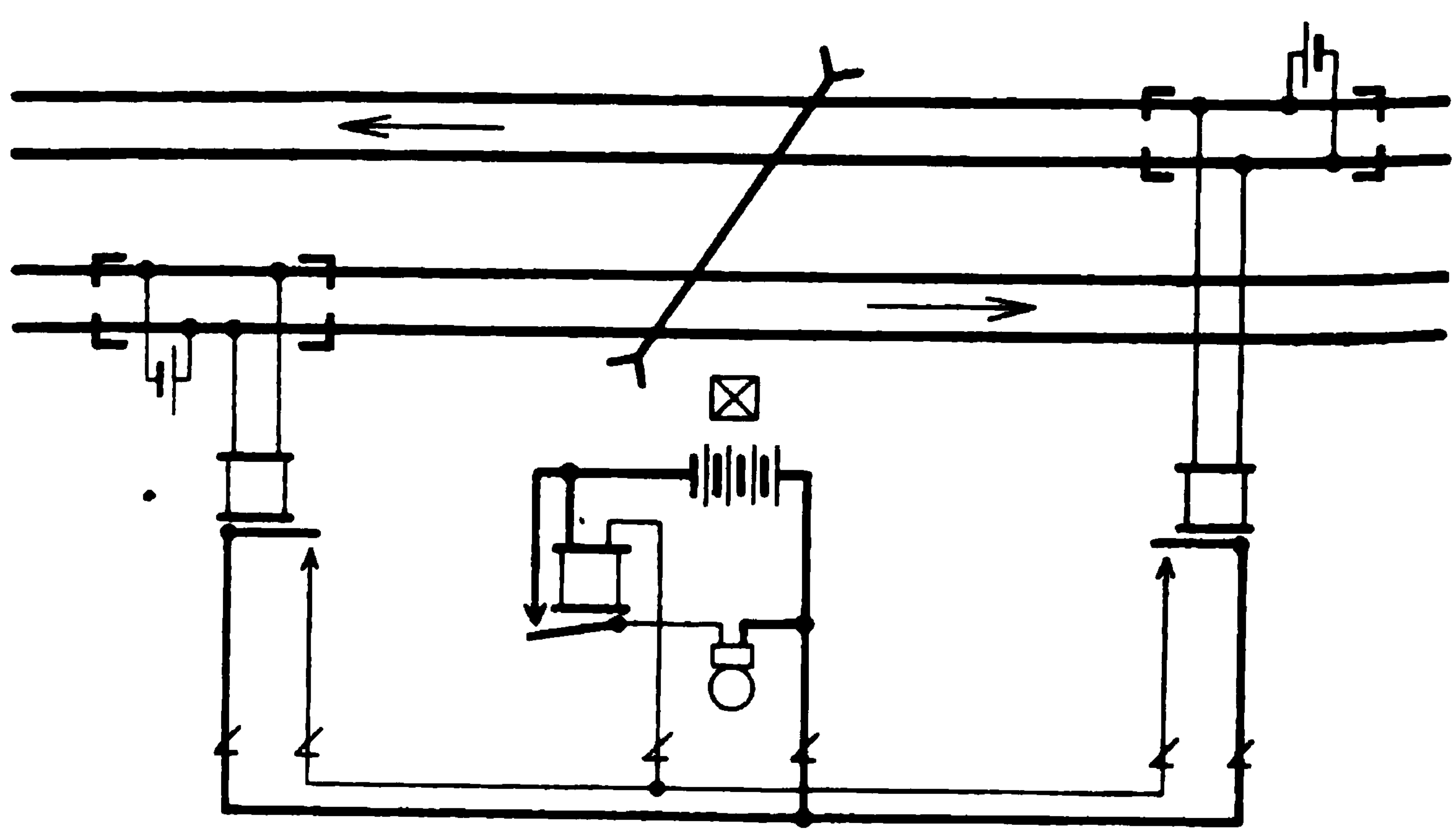


Fig. 86

in Fig. 86. This illustration shows the use of normally closed track circuits, as mentioned in Art. 203. Separate batteries are sometimes provided where the bell requires a higher voltage than the line circuit.

205. In the arrangements shown in Figs. 84-86, the line circuits are normally open and on that account are sometimes considered undesirable, due to the probability of their failing

to give warning of the approach of a train, in case of the interruption of these circuits.

The arrangement illustrated in Fig. 87, overcomes this objection as it employs a normally closed line circuit.

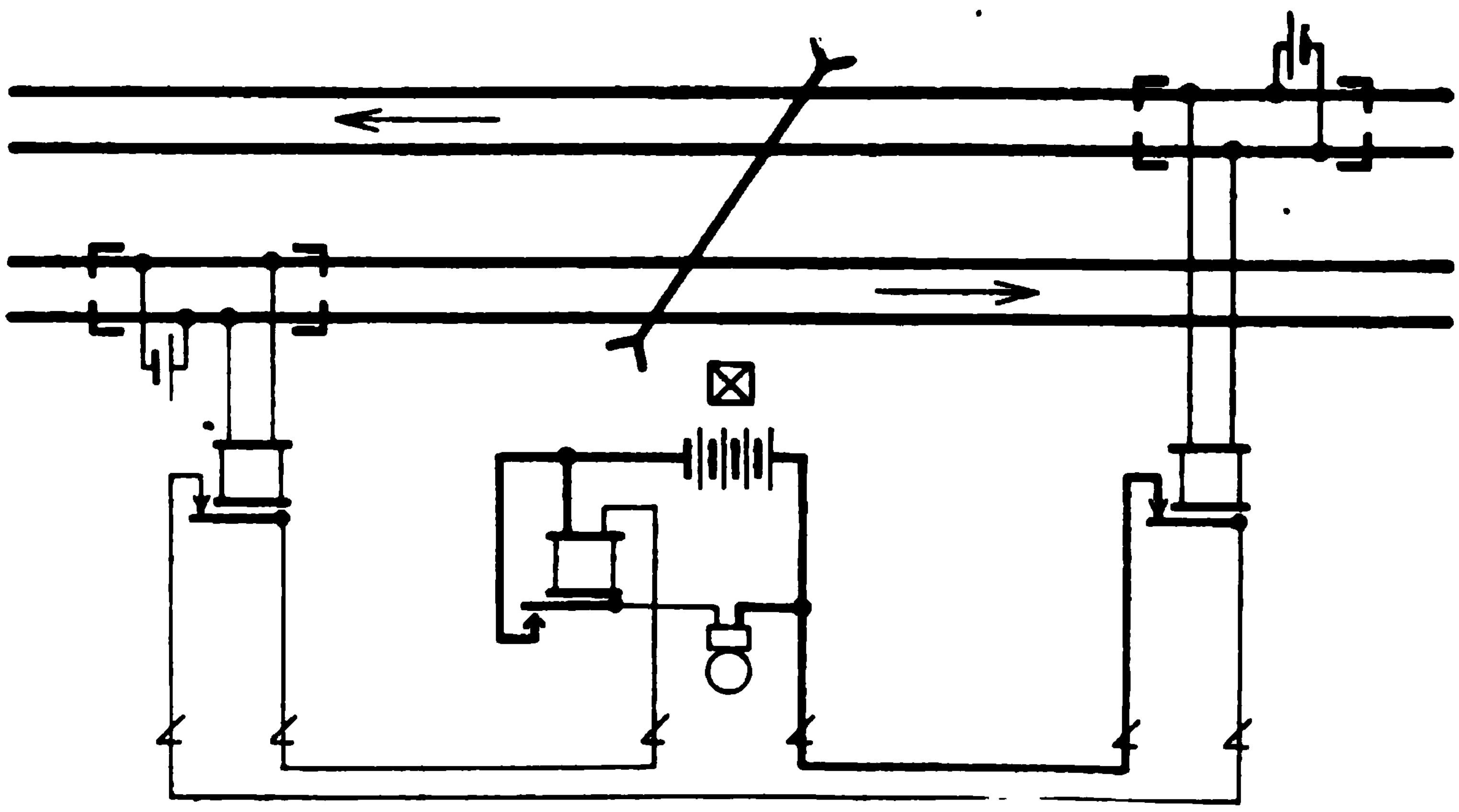


Fig. 87

206. Separate annunciators are provided, in some cases, for each track, one method of arranging the circuits, Fig. 88, being a modification of those shown in Fig. 87. In this connection it should be noted that the circuits shown in Figs. 84-86, may be modified in a similar manner. In such instances, it is customary to provide for each track, annunciators which emit different sounds, such as bells and buzzers, or bells of distinctly different tones, locating them in different parts of the cabin.

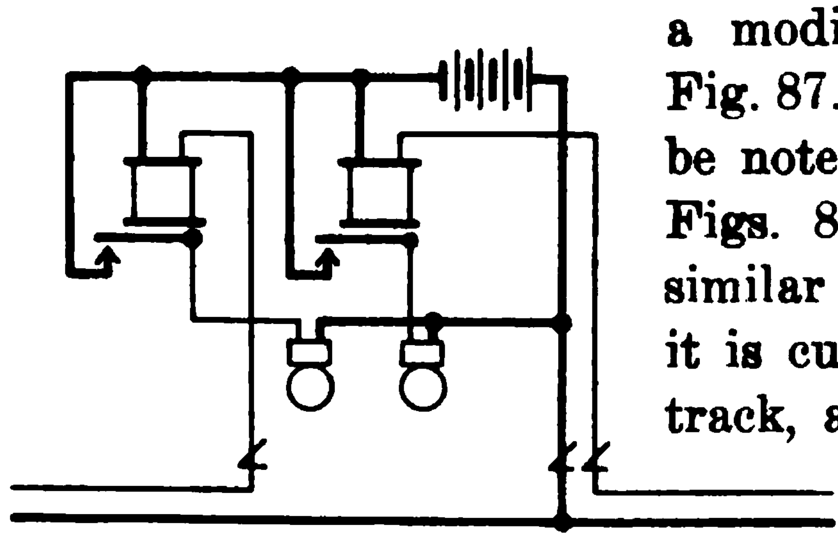


Fig. 88

207. In Figs. 87-88, it is evident that crossed line wires would tend to prevent the bell from announcing the approach of a train. This may be avoided by placing the line battery at the track relay, as in Figs. 89-90, in which case *two* line relays, one for each track, will be required, whether two bells or only one are employed.

If two bells are used, their connections will of course, be similar to those shown in Fig. 88, but if only one bell is to be

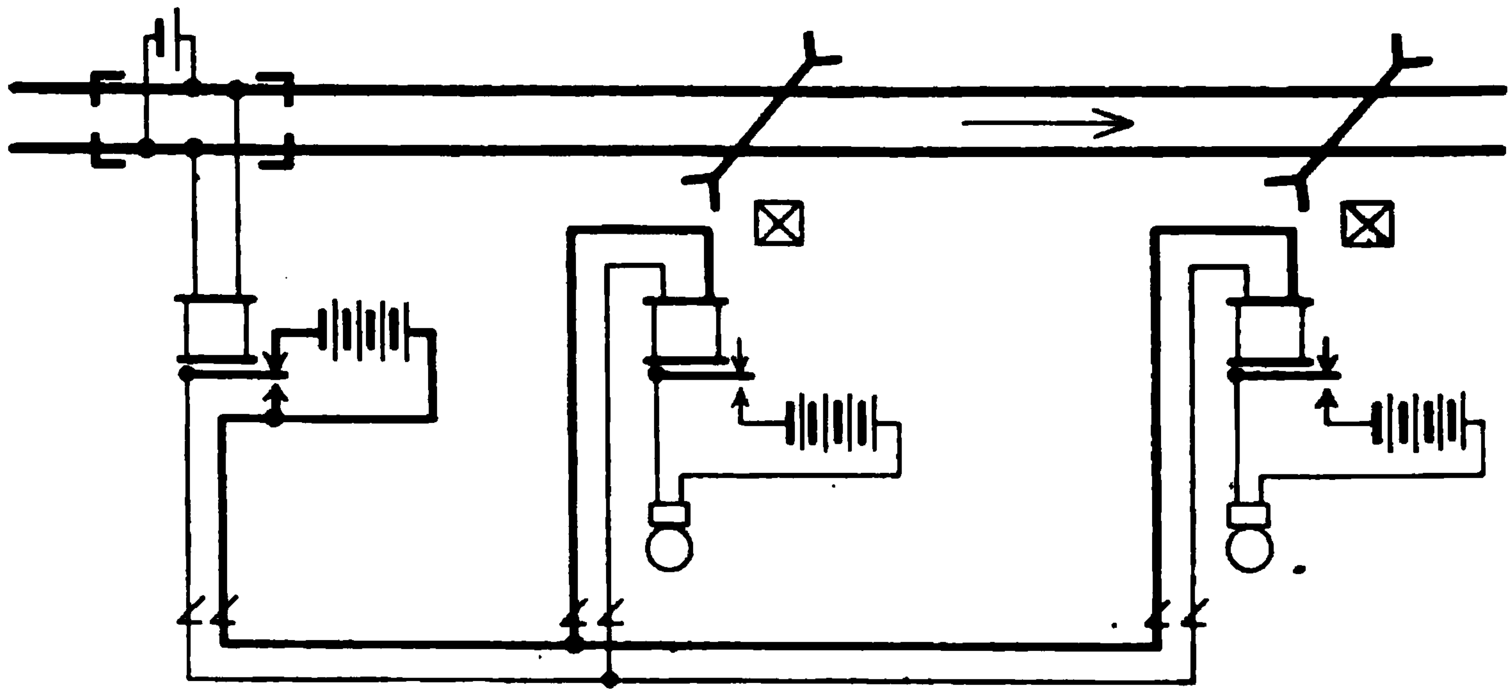


Fig. 89

operated, the back contacts of the two line relays will be connected in multiple.

208. When two or more crossings are located close to each other, and it is desired to operate annunciators at each, they are frequently controlled by the same track circuit, as illustrated in Fig. 89, which is an application of the arrangement just described.

209. Any of the arrangements illustrated in Figs. 84-88, or their variations, may be operated by track instruments, although when so controlled they usually operate intermittently as the train is passing the instrument.

210. Annunciators are frequently arranged to ring continuously from the time the train passes the starting point, until it reaches the crossing. For this purpose any of the methods described for operating regular crossing alarms may be employed.

211. As annunciators are not intended to warn the public at the highway of the approach of a train, but simply to indicate this fact to the flagmen, it is not necessary to keep the length of track over which they operate as closely defined as with the regular alarms, and therefore many of the complications encountered where there are two or more crossings, or where

other apparatus is controlled over the same length of track, are usually avoided. For instance, with the arrangement shown in Fig. 90, both track relays control other signal apparatus,

Fig. 90

and in addition, the annunciator is operated by relay A, relay B being located too near to the crossing to control it. If relay A is somewhat farther away than necessary, it is not usually considered desirable to install a cut section between these two points, as would probably be done in the case of a regular crossing alarm. It will also be noted that the annunciator stops operating when the rear end of the train passes point X, further announcement being considered unnecessary.

212. If desired, interrupting keys may be installed with any of the annunciator arrangements, to enable the flagman to stop the annunciator after it has been started by a train on one track, in order that it may again start if a train should approach on the other track, or that he may hear another annunciator (if two or more are used) when it operates.

213. In some cases, instead of the ordinary relays which control the bell circuits, *indicators* are used, one for each track. These instruments are made similar to a relay, but the armature in addition to operating contacts, also operate a movable part, generally a colored disk or an arm, thus giving an indication of the action of the relay and consequently an indication of the position of a train.* Of course, where indicators are used both *visual* and *audible* indications are given. Another advan-

*Various types of *indicators* will be described in detail later.

tage of the use of indicators, is that if the bell circuit fails, the indicator will continue to give warning.

214. **Gate Signals:** An arrangement of circuits for operating the gate signals mentioned in Art. 4, is illustrated in Fig. 91.

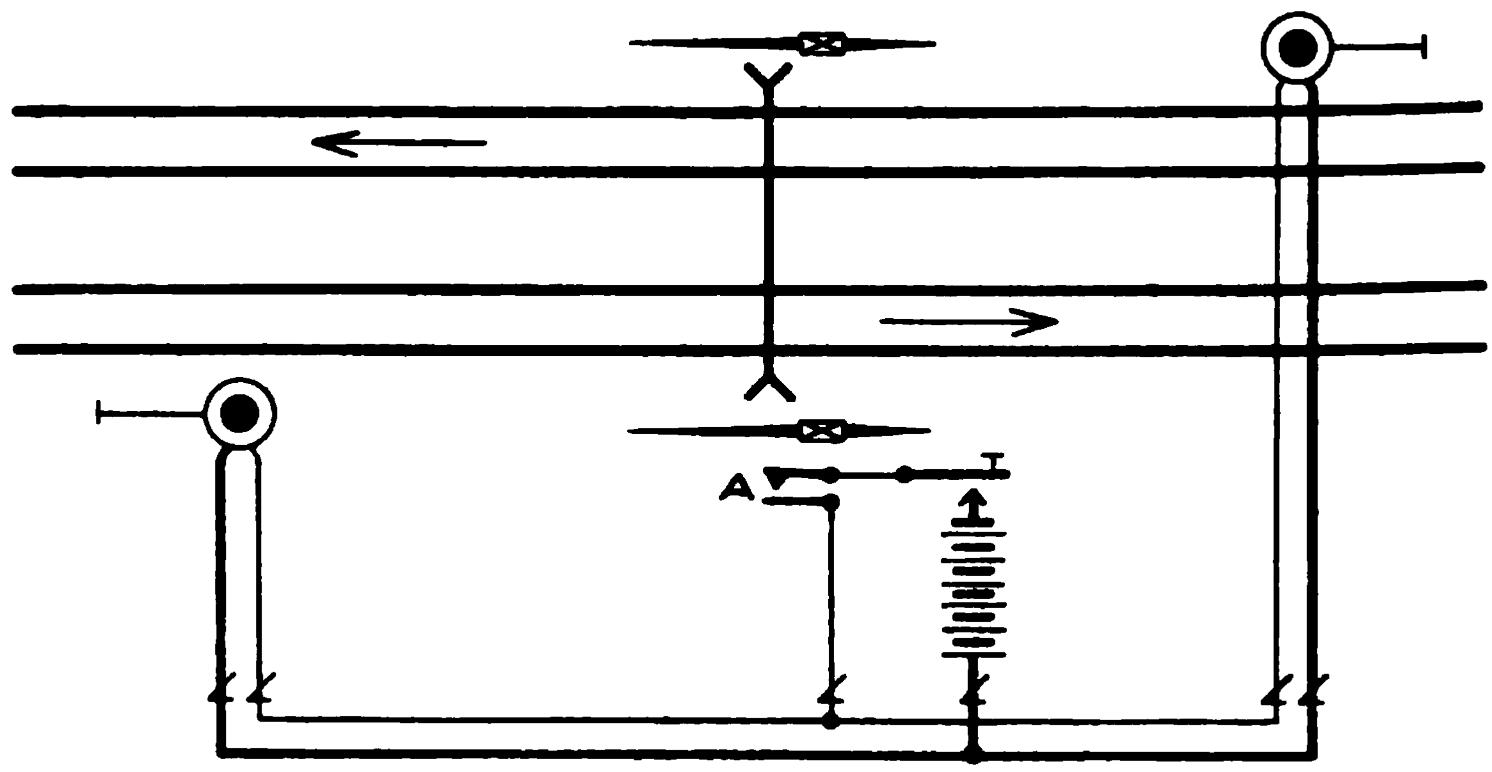


Fig. 91

Circuit controller A is operated by the gates, the arrangement being such, that when the controller is closed, the gates are in a position to prevent access from the highway to the tracks. When a train is approaching, the flagman closes the gates and then closes and holds the spring key until the train has passed the crossing, thus completing the circuit for the signals,* causing them to assume a position indicating "proceed".

In some instances circuit controller A is omitted, the spring key being located on the gate in such a manner that the flagman cannot reach it until the gates are closed.

215. Where two crossings are located close together, one signal may be used to control movements over *both* crossings, the circuit controlling the signal being broken *in series* through the circuit controllers on both gates, thus insuring that they are closed, before the signal can be operated to indicate "proceed".

216. At some points the gates and signals are controlled by levers in an *interlocking machine.* The common arrangement

*Described in **Power Operated Signals.**

is such that when the levers are in the *normal* position the signals indicate stop and the gates close the highway. If the signals are cleared the position of the levers cannot be changed, that is, the gates must continue to block the highway and inversely, if the position of the gates is changed, the signals cannot be cleared; in other words, the signal levers lock the gate levers *normal.*

EXAMINATION QUESTIONS

(1) State the purpose of highway crossing alarms.

(2) Under what conditions are buzzers employed?

(3) What is the most common type of automatic alarm used at highway crossings?

(4) What name is generally applied to short track circuits which operate crossing alarms?

(5) Describe briefly the operation of track instruments.

(6) How far above the ground is it customary to mount alarm bells?

(7) To what is the term "nigger head" frequently applied?

(8) Are the circuits controlled by the device shown in Fig. 29, carried to contacts 4 and 5, or 25—27?

(9) When is it desirable to employ high voltage apparatus in crossing alarm installations?

(10) Why is it sometimes desirable to omit fuses from lightning arresters placed in line circuits?

(11) What voltage is generally employed in the alarm circuit?

(12) (*a*) At what distance from the crossing is it customary to have an approaching train start the alarm operating? (*b*) What governs this distance?

(13) If two crossings are located 900 ft. apart, is it generally considered desirable to start both alarms at the same time?

(14) (*a*) What is a common wire? (*b*) How are they indicated on drawings?

(15) Why are relays sometimes wound to a high resistance, such as 500 ohms?

(16) Why is it desirable to test alarms frequently?

(17) Why is it not always desirable to employ back contact shunts?

(18) (*a*) What is a stick relay? (*b*) What is a stick circuit?

(19) Which are generally the most desirable, normally closed or normally open line circuits?

(20) What trouble may be caused by an overloaded common wire?

(21) Why is it good practice to locate the instrument at one end of the line and the battery supplying current to it, at the other end, in normally closed circuits?

(22) (*a*) What is a "starter"? (*b*) A "stopper"?

(23) For what purpose are interrupting devices employed?

(24) (*a*) What would be the result of crossed line wires east of the crossing, with the arrangement shown in Fig. 65? (*b*) What with the arrangement shown in Fig. 66?

(25) How would a broken line wire affect the arrangements shown in Figs. 65-66?

(26) With the arrangement shown in Fig. 74, does the alarm stop when the head or the rear of the train passes the crossing?

(27) What dangerous effect would result from a break in wire 3, Fig. 40?

(28) What would be the probable effect of a cross in the line circuit, sketch B, Fig. 43?

(29) What effect would a train moving against traffic have upon the alarms shown in Fig. 43?

(30) What effect upon the time circuit breaker, Fig. 69, would be produced by a cross in the line?

SINGLE TRACK ARRANGEMENTS

217. Track Circuit Control: When crossing alarms are installed on single track, it is necessary to provide an arrangement which will cause the alarm to operate when trains approach the crossing from *either* direction, and also to so arrange the apparatus that when a train passes the crossing the alarm will cease to operate. For instance, in Fig. 92, a train moving from *west* to *east* should operate the alarm while on track circuit A, but not while on track circuit B, and inversely, a train moving from *east* to *west* should operate the alarm while on circuit B, but not while on circuit A.

218. The foregoing is accomplished by the use of an *interlocking relay* as shown in the illustration.

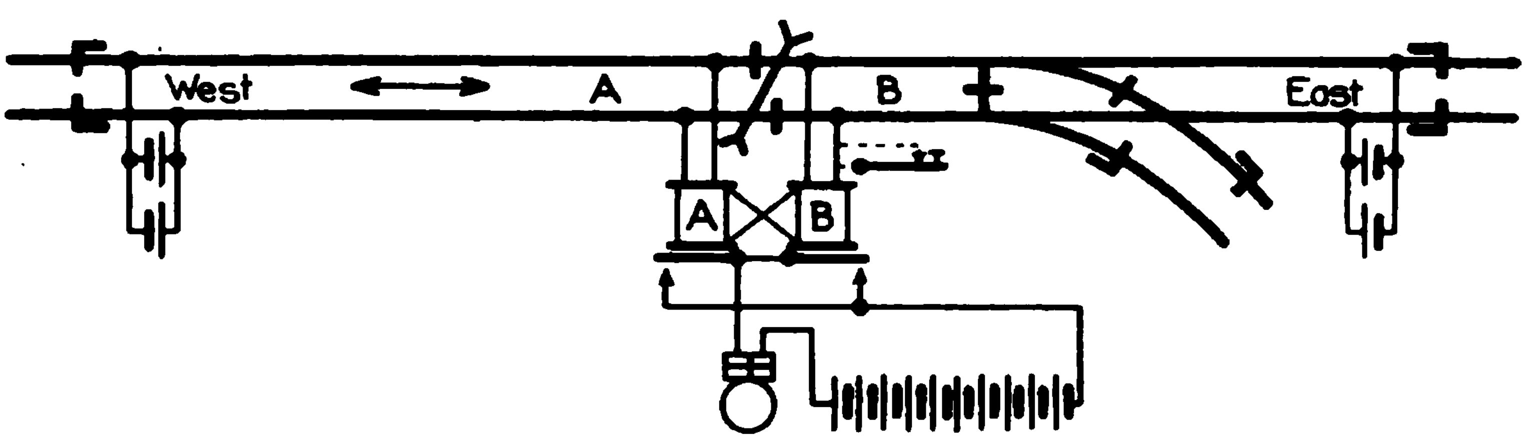


Fig. 92

When a train approaches from the west it shunts coil A, releasing its armature and closing the bell circuit through the back contact on that side of the relay. When the train passes the crossing onto circuit B, it shunts coil B, releasing its armature, which is prevented from closing its back contact, by means of the interlocking feature.* As the rear end of the train passes off circuit A, coil A is energized, thus attracting its armature and opening the bell circuit. When the train passes off track circuit B, the relay is restored to its normal position.

*It is desirable to review that portion of **D. C. Relays** which treats of the interlocking type.

Of course, it is understood that the operation of the relay is reversed for a train moving in the opposite direction.

219. If before an east-bound train leaves circuit B, a following train should enter upon circuit A, the back contact controlled by coil A, would of course, again cause the bell to ring.

220. It will be observed that test keys may be employed in a similar manner to that described for double track arrangements, which is generally true of other arrangements hereafter shown. However, unless the keys are operated by a person who is familiar with the action of the interlocking relay, the condition of the interlocking feature will not be ascertained.

The dangerous condition referred to in Art. 99, regarding the use of *series* testing keys, will be evident from a study of Fig. 92. If such a key were used as shown dotted with coil B, and resistance should develop between its contacts, this coil might not pick up its armature after an east-bound train had passed off circuit B, and consequently the next west-bound train would fail to operate the alarm until it had passed the crossing onto circuit A.

221. If after an east-bound train had passed the crossing but not off circuit B, it should stop and back over the crossing, the alarm of course, would not operate while the train is on circuit B, but would again do so when it passed onto circuit A.

This same condition would be produced if a west-bound train passed onto circuit B, from the siding, before an east-bound train had passed off this circuit. Although the bell would not ring while this train was approaching the crossing, its rate of speed would usually be low and generally not considered dangerous. However, it is sometimes deemed advisable to provide an arrangement to overcome this condition and also to avoid the unnecessary ringing of the bell after the west-bound train has passed the crossing.

222. A method of accomplishing this is illustrated in Fig. 93. As will be seen, it is an application of the switch box arrangement described in connection with Fig. 76. The reversing of the switch to allow the train to proceed from the siding to the main, closes the circuit for battery C, thereby energizing coil B and consequently causing the relay to assume its normal position, ready to operate for this train.

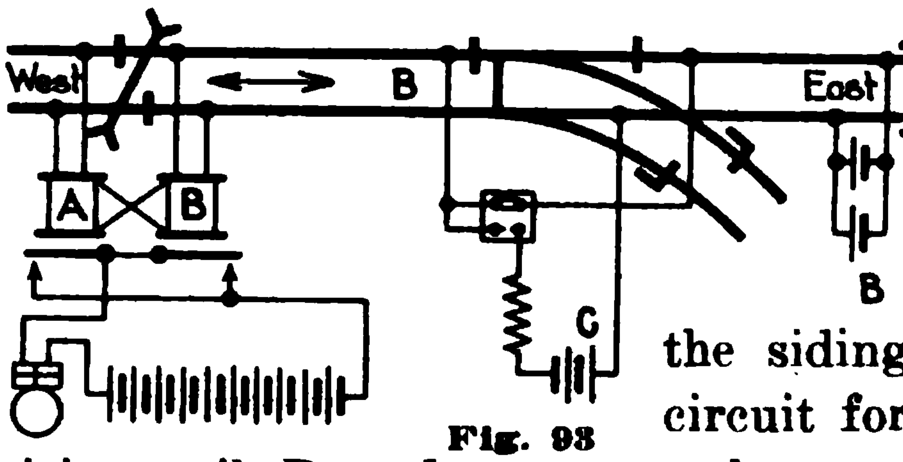


Fig. 93

This arrangement may be used to advantage at switches facing in either direction, as it often happens, in cases where the switch faces away from the crossing, that a train will pull out of the turnout close behind another train and then back over the crossing.

223. Another arrangement, Fig. 94, which is employed at switches that face away from the crossing, is desirable for use when the switch is at the end of a passing siding where trains coming from the siding frequently continue away from the crossing. If such a move were to be made with a switch wired as shown in Fig. 93, it is evident that a false alarm would be given after the switch had been thrown to its normal position.

224. This condition is avoided by employing an additional interlocking relay D—E, at the switch, as shown in Fig. 94. Magnet E, whose front contacts are so arranged that they *will not open* if the magnet is de-energized when the armature is locked, controls circuit F, as if it were an ordinary relayed track circuit. If when circuit E is unoccupied, magnet D is de-energized by opening the switch, its armature locks that of magnet E. Thus the alarm is kept

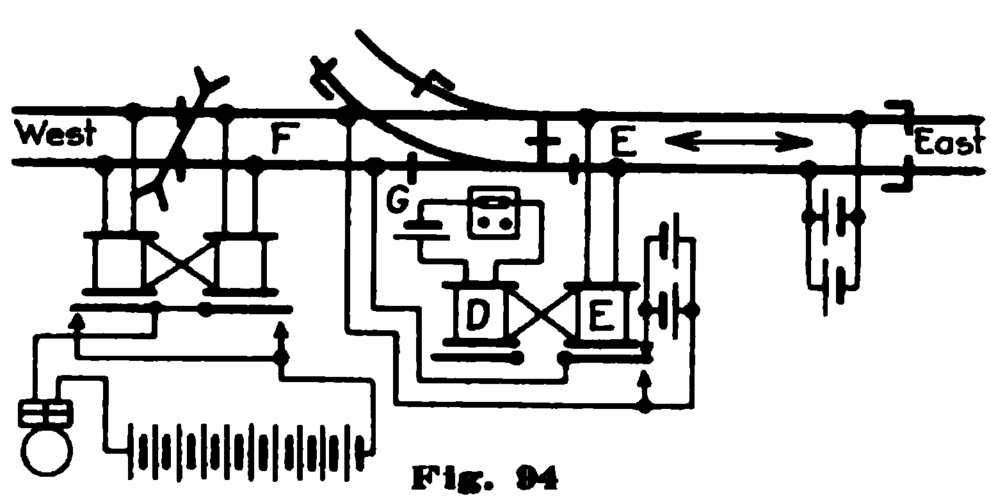


Fig. 94

from operating with the train on circuit E, after the switch is thrown to its normal position. If the train instead of proceeding eastward, should move westward after closing the switch, it would shunt circuit F, and thus give a proper alarm at the crossing.

225. It will be observed that in case battery G fails or any part of its circuit becomes broken, the alarm for a west-bound train would be shortened, that is, it would commence to operate only when circuit F was shunted. This may be considered an objection, especially when the switch is close to the crossing.

226. If it is not desired to employ a switch box, magnet D may be controlled by a short track circuit, occupying the ''nary fouling section, as In this instance insulated switch rods are used instead of the cut-out around the switch This is desirable in order l a dead section at the which if of sufficient o contain a light engine

Fig. 95

leaving the siding, would allow coil D to attract its armature, before coil E was de-energized, resulting in a false alarm, if the engine should continue moving eastward.

It should be noted that with the interlocking relay connected as shown, the back contact shunt is not provided on the relayed track circuit.

227. Alarms are sometimes operated at crossings on two tracks which join at a switch within the limits of the track section over which the alarms are controlled. Such an arrangement is shown in Fig. 96,** this being a development of the circuits shown in Fig. 95. In this case the short track circuit at the switch is arranged so that it will be shunted by a train

*This illustration shows the connections for a particular type of interlocking relay, although any of the ordinary types may be employed.

**It will be noted that the bell circuits are omitted.

on *either* track. The interlocking relay at the switch is so adjusted that the front contacts operated by coil A will remain closed if its armature is the last to release, thus preventing an east-bound train on either track from giving a false alarm at the crossing on the other track when the train shunts circuit A. This interrupting circuit should be made as short as possible so as not to interrupt a continuous alarm for a west-bound train, as apparently would be the case if these circuits were long enough to contain an entire train.

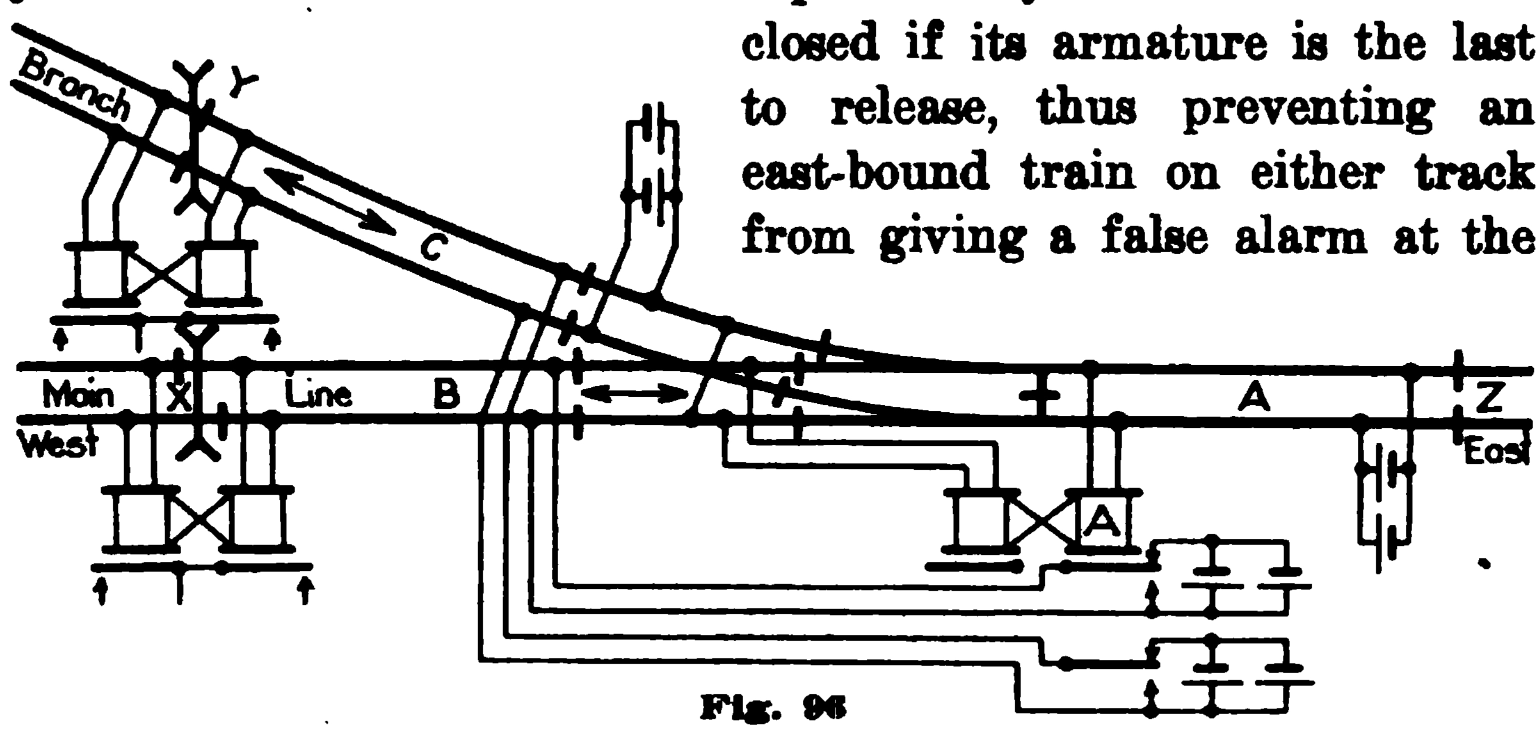


Fig. 96

228. A method of operating a crossing alarm for single track, without the use of an interlocking relay, is shown in Fig. 97. In this case a short normally open track circuit (one or two rail lengths) is arranged at the crossing, being employed to operate a stick relay.

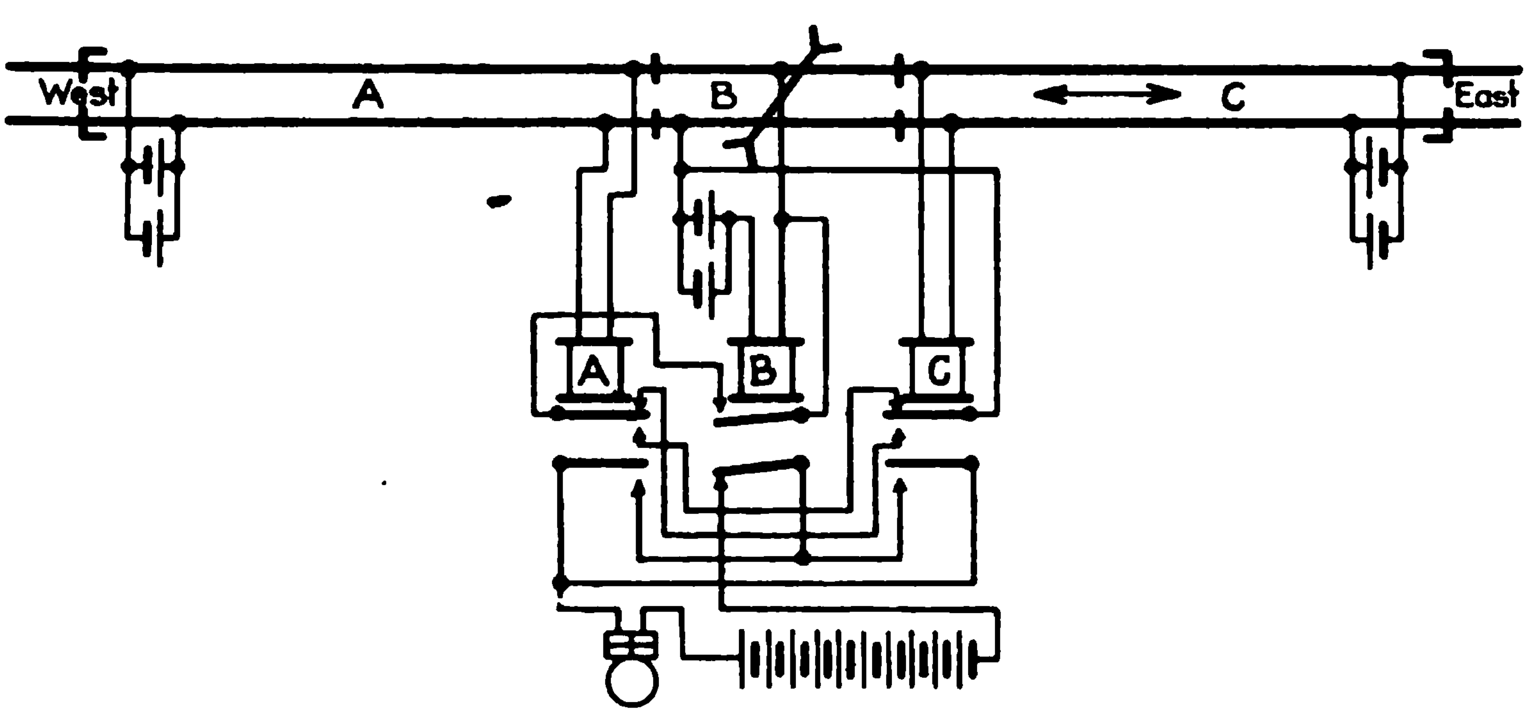


Fig. 97

229. Assuming that a train is traveling eastward toward the crossing, it will first de-energize relay A, completing the bell circuit through its lower back contact and through the

back contact on relay B. When the train reaches circuit B, relay B is energized, thus breaking the bell circuit. After the rear end of the train clears circuit A, relay A picks up its armature and closes a stick circuit for relay B, through its front contact and through a back contact on relay C, which is now de-energized by the forward end of the train. The train passing off circuit B does not affect the position of relay B, as it remains energized due to the stick circuit just mentioned. As the train proceeds and leaves circuit C, relay C picks up, breaking the stick circuit and restoring all relays to their normal position. The operation of the relays for a train moving in the opposite direction is, of course, reversed.

230. If while an east-bound train occupies circuit C, thus keeping relay B energized, a following train should enter circuit A, the stick circuit would be broken at the front contact on relay A, and consequently relay B would be de-energized and the bell would again ring until this train reached circuit B, and picked up its relay.

231. Another method of operating a single track alarm without an interlocking relay, is illustrated in Fig. 98, this

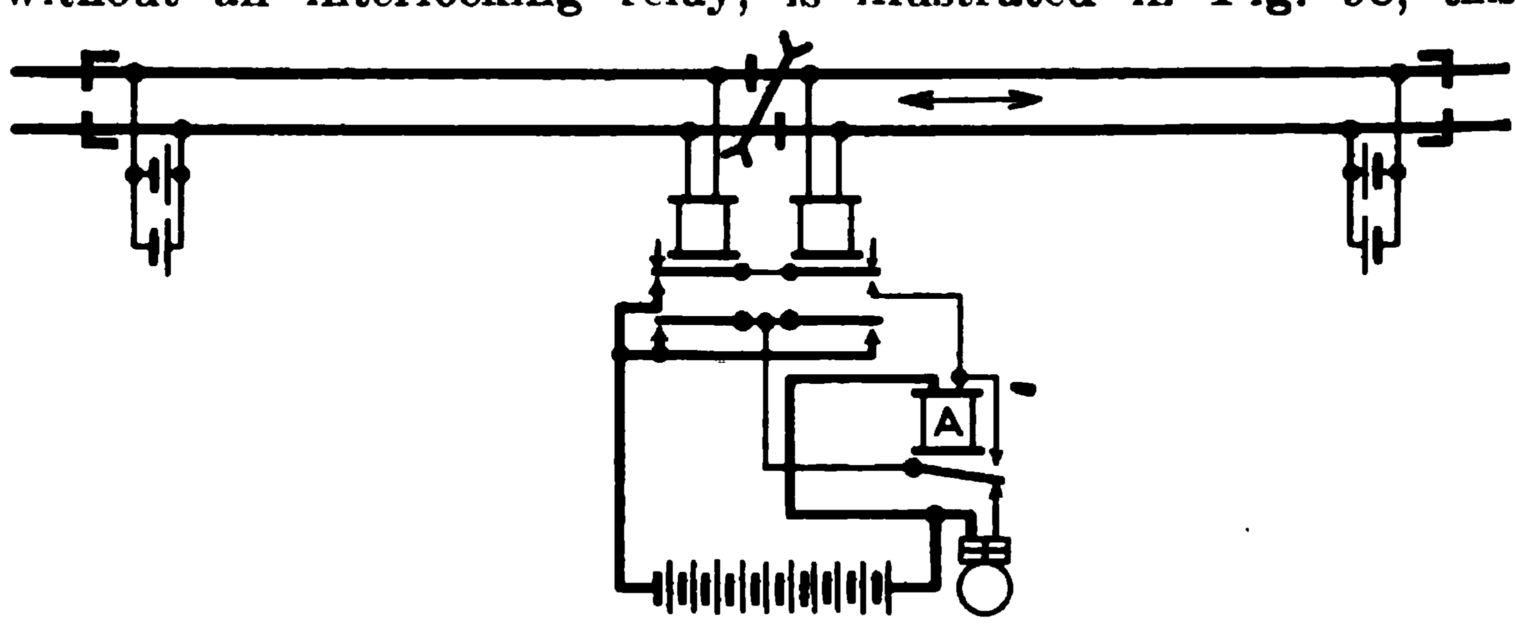


Fig. 98

being a development of the cutting out principle shown in Figs. 77 and 79. When a train is passing from one track circuit to the other, relay A is energized through back contacts on *both* track relays, thus stopping the bell and completing the stick circuit. Relay A remains energized until the train passes off the track circuits, at which time, both track relays being energized, the stick circuit is broken and relay A de-energized.

232. This method is not as safe, in the case of a following train, as that shown in Fig. 97, as it is evident that if trains occupy both track circuits, the bell will fail to ring. However, it is more convenient, as it may be substituted for an interlocking relay without altering the insulated rail joints or the rail connections, which is of course, a valuable feature in case of emergency.

233. When two crossings are located far enough apart to provide a ringing section between them, the arrangement il-

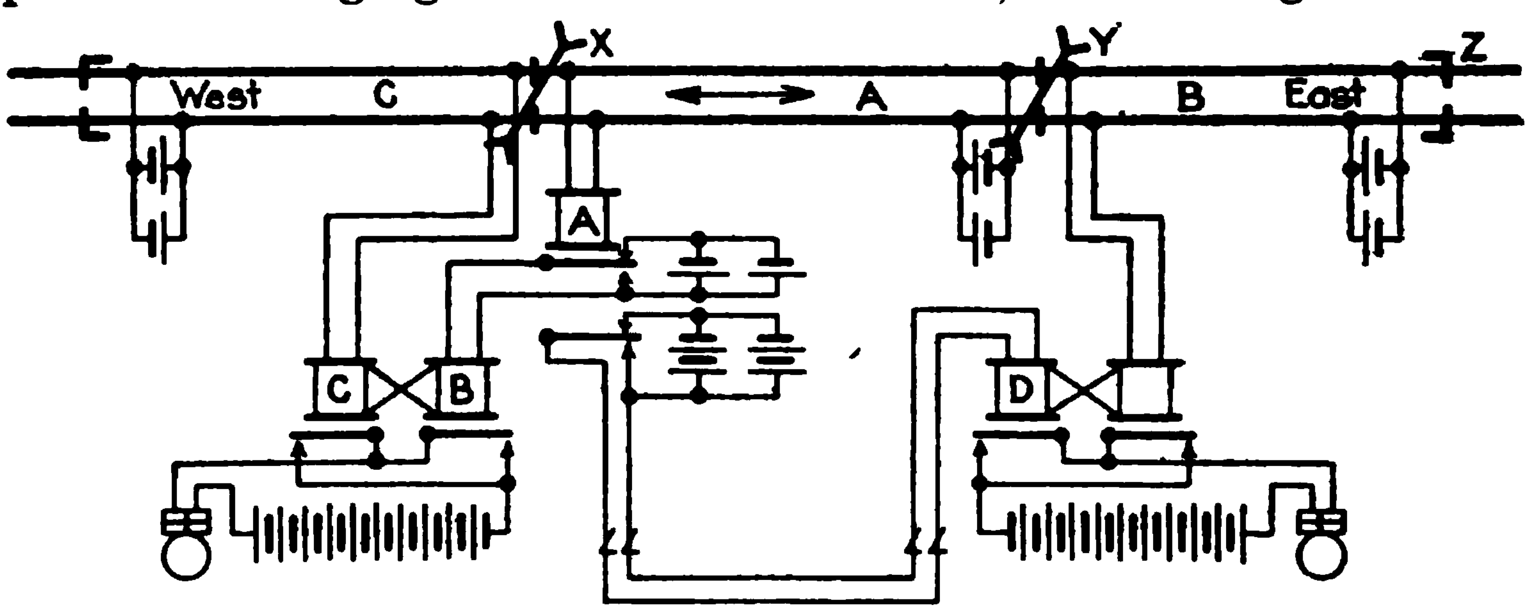


Fig. 99

lustrated in Fig. 99, is often employed, the relay of track circuit A, controlling one side of each interlocking relay.

234. It should be noted that if test keys are to be used with these circuits, it will be necessary to provide four keys, one of the keys for circuit A, being used at the relay for testing the westerly bell, and the other at the battery for testing the easterly bell.

Care should be exercised when testing with keys thus arranged, because when either key is operated both bells ring and therefore traffic at one crossing is liable to be delayed while the bell at the other crossing is being tested. Another reason for exercising care is the likelihood of producing a dangerous condition; for instance, if an east-bound train should enter circuit C, just after the key at crossing Y was operated, the bell at crossing X would stop ringing as soon as the test key was released, as the interlocking feature would prevent the back contact on coils C from closing. The bell would therefore remain silent until the train shunted circuit A, when it would ring until the train passed off this circuit.

235. If there were another crossing at point Z, the arrangement controlled by track circuit A may be repeated for circuit B, in fact this arrangement may be repeated any number of times. This also is true of modifications of these circuits, shown in Figs. 100-105.

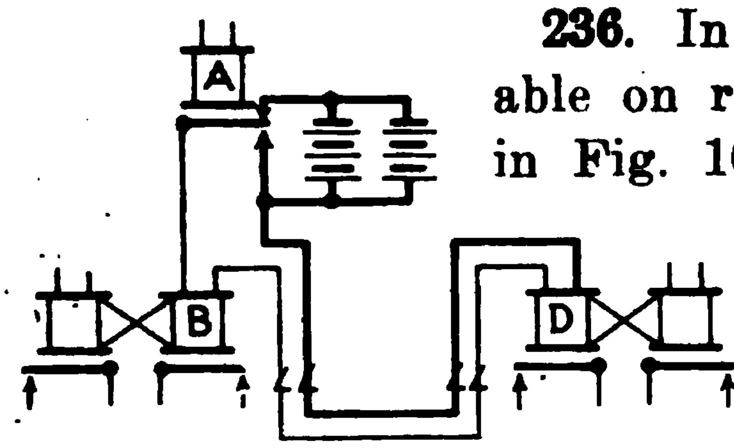


Fig. 100

236. In case only one contact is available on relay A, the arrangement shown in Fig. 100, may be employed, although it is not as efficient, as a break or poor connection at any point in the line circuit would cause a failure of both bells, instead of only one.

237. The interlocking relays shown in Figs. 99-100, have the same resistance in each of the coils; that is, the same relay as is used in Fig. 92, may be employed in these cases. As the resistances of these coils are quite low, it is generally desirable to use gravity batteries on the line circuits, arranging the cells *in multiple* or *multiple-series* as shown, to provide broken jar protection. Of course, if desired, a plain *series* arrangement may be used.*

238. By altering the resistance of coils B and D, the arrangement illustrated in Fig. 101, may be used. With this scheme the two coils are wound to at least 500 ohms resistance and are connected *in multiple,* being furnished with current from one of the bell batteries. As their resistance is much higher than that of the line, the difference in the current through the two coils, on account of the line resistance. is negligable.

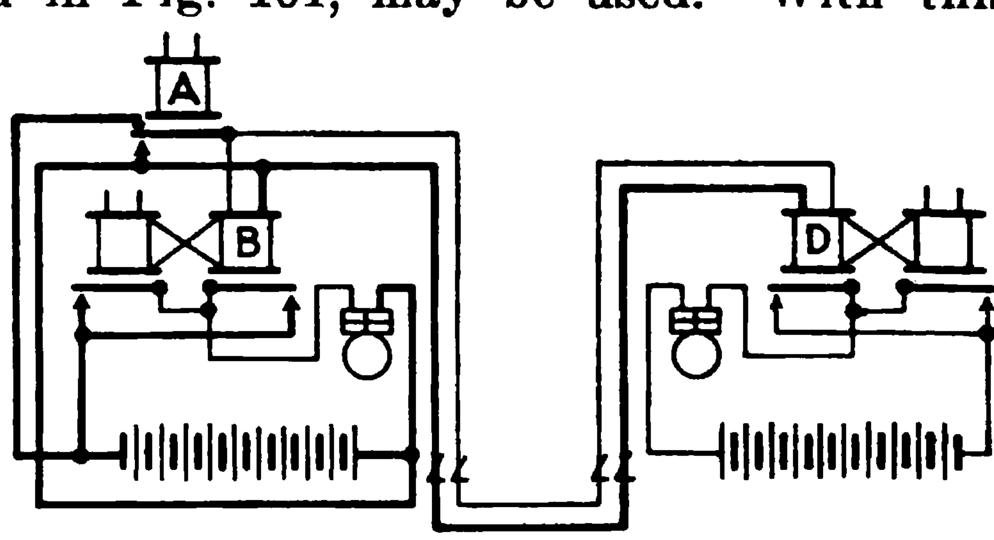


Fig. 101

*Although series arrangements are shown hereafter with similar line circuits, multiple arrangements may of course, be employed.

239. In some instances, coils B and D are each wound to a resistance of 16 ohms, and to equalize the current through each of these coils, a resistance, equal to that of the line, is placed in series with coils B.

240. If the return for current from coil D is on a common wire along which other current is also flowing, a break in this wire, for instance, at point X, Fig. 102, may cause current, passing from E to F, to follow the path indicated by the arrows and thus falsely energize both coils as shown.

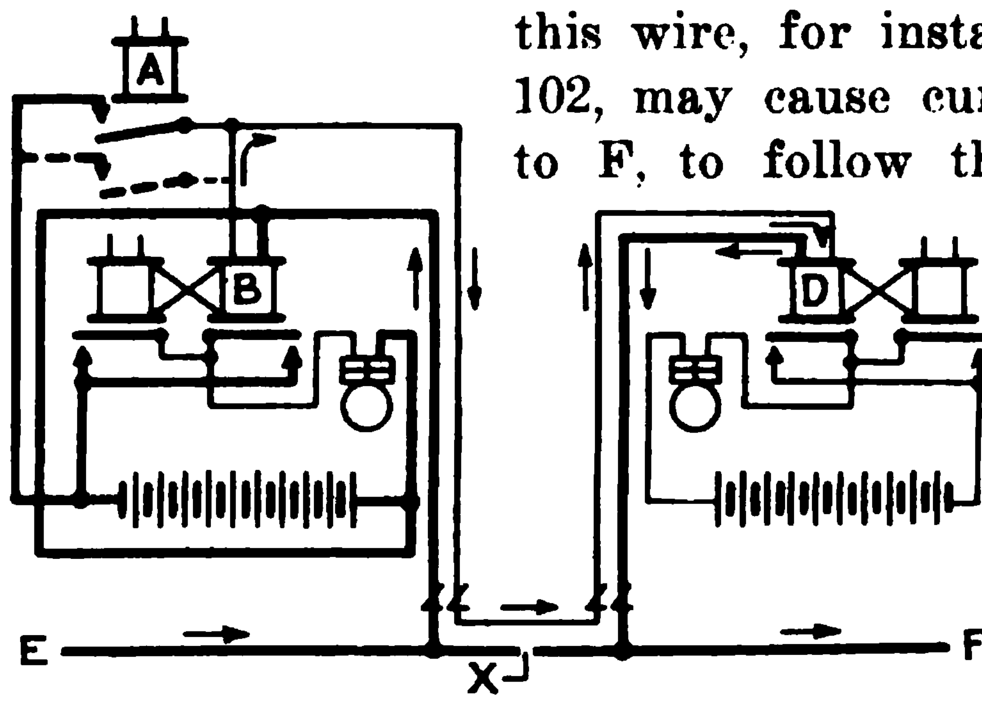


Fig. 102

To avoid such an occurrence an additional contact may be used on relay A, the controlling wire to coil B, being carried through this contact as shown dotted, instead of to the upper wire.

Another means of overcoming this condition is to place coils B and D in series, winding each of them to about 200 ohms resistance, and omitting the back contact shunt on relay A.

241. A method of arranging alarm circuits for the layout just described, which avoids the use of wires between the crossings, is shown in Fig. 103.

In this arrangement magnet B operates as a multiple clearing relay, being wound to a higher resistance than magnet D. It is of course, subject to the possibilities of failure on account of a broken rail, etc., as described in *D. C. Track Circuits,* which would tend to

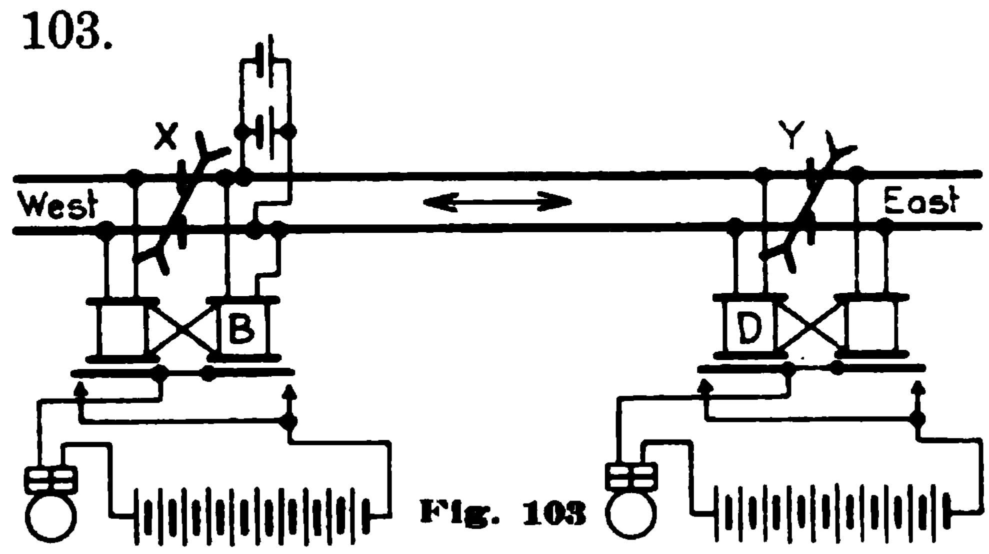


Fig. 103

shorten the alarm given at crossing X, by a west-bound train, and a test key at this crossing would not detect the defective condition. However as such a defect in the track circuit would tend to prevent magnet D from picking up and thus cause the bell at crossing Y to ring continuously, the trouble would probably soon be discovered.

242. Another method sometimes employed to avoid the use of wires between the crossings, is illustrated in Fig. 104. The

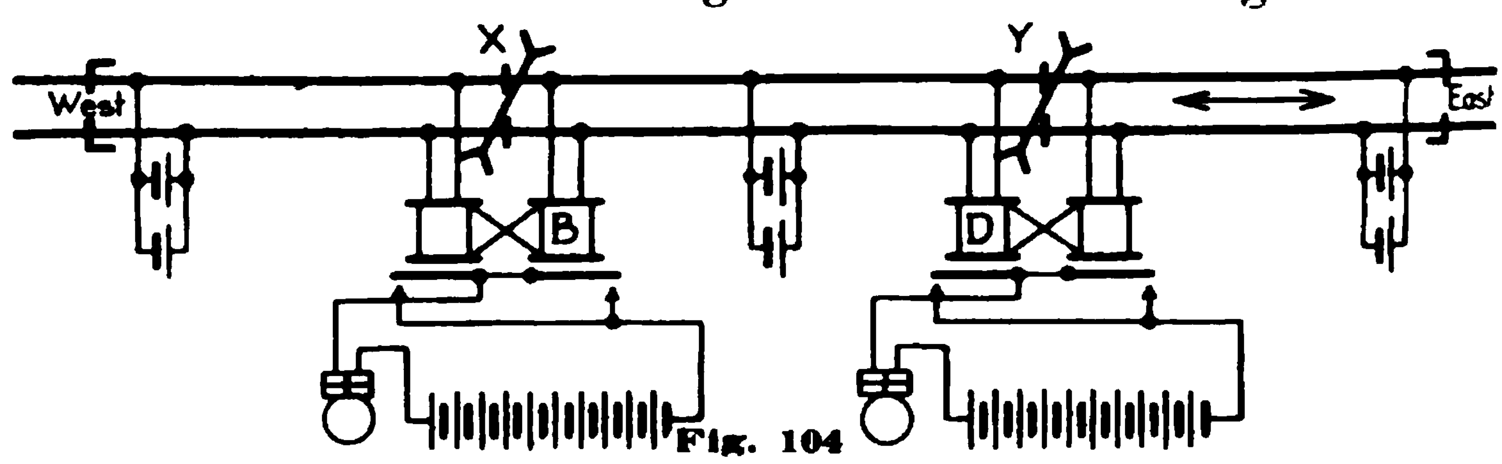


Fig. 104

battery for the middle track circuit is connected to the rails at its center, feeding both ways to energize magnets B and D, which are of equal resistance. With this arrangement the possibility of failure to release, on account of a broken rail, etc., is divided evenly between the two magnets, and while one of them would, in such cases, probably ring continuously, the other would at least indicate the presence of a train between the battery and its own end of the circuit.

243. The circuits described in connection with Figs. 99-104, are for use with interlocking relays having but *one contact* on each side. If relays with *more contacts* are obtainable, the arrangement may be simplified somewhat, as shown in Fig. 105.

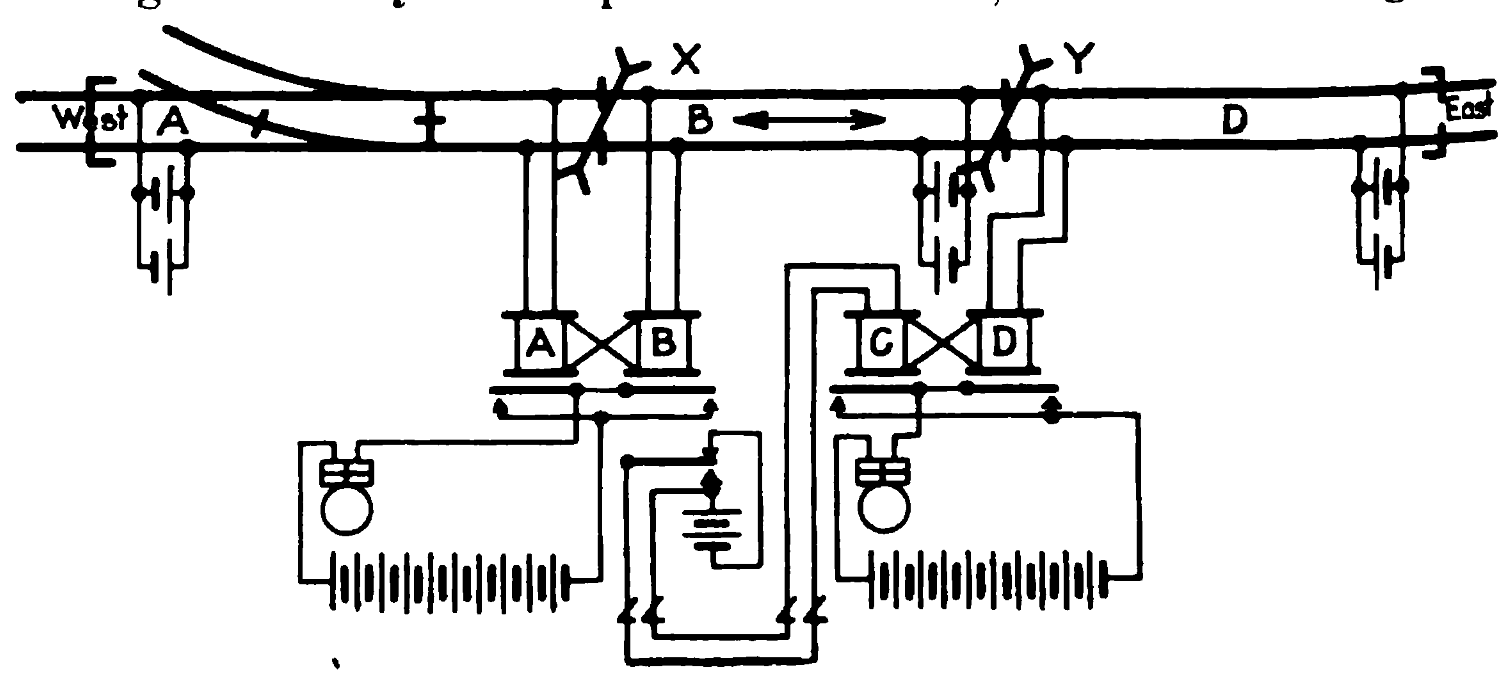


Fig. 105

It will be observed that the additional contact operated by coil B of one interlocking relay, controls coil C of the other relay.

244. This arrangement is satisfactory with types of relays that allow their front contacts to *close* when the armatures are interlocked. However, with types in which the armature that drops first is *kept from closing* its front contact when the other armature is down, a bad condition may arise if a train should stop and back up, or if there is a switch in one of the circuits; for example, in Fig. 105, a west-bound train would ring both bells properly, but if the armature of coil A keeps that of coil B from closing its front contact, coil C will remain de-energized, thus keeping that relay locked until the train has entirely passed off circuit A. Therefore, if the train should stop in circuit A, and back over both crossings, it would not, of course, ring the bell at crossing X until it reached circuit B, but on account of the speed which it could develop, a much more dangerous condition would result from its failure to ring the bell at crossing Y until it reached circuit D. It is apparent that this condition may also be caused by an east-bound train coming out of the siding onto circuit A, before the west-bound train has cleared this circuit, although this may be remedied in the manner shown in Figs. 93-95.

245. The line battery shown is of the gravity type (coils C and D being of equal resistance) but if desired, current from the bell battery at X may be used on the line circuit and coil C wound to a suitable resistance.

246. When two crossings, located close together, are to be protected by alarms which begin to operate at the same point and each stop as the train passes it, the arrangement illustrated in Fig. 106 may be used, when the interlocking relays have but one contact on each side.

In this and similar arrangements the wires between the crossings are shown in trunking (Art. 101) although line wires provided with lightning arresters may of course be employed.

247. Another arrangement which accomplishes the same result but uses two instead of four batteries, is illustrated in

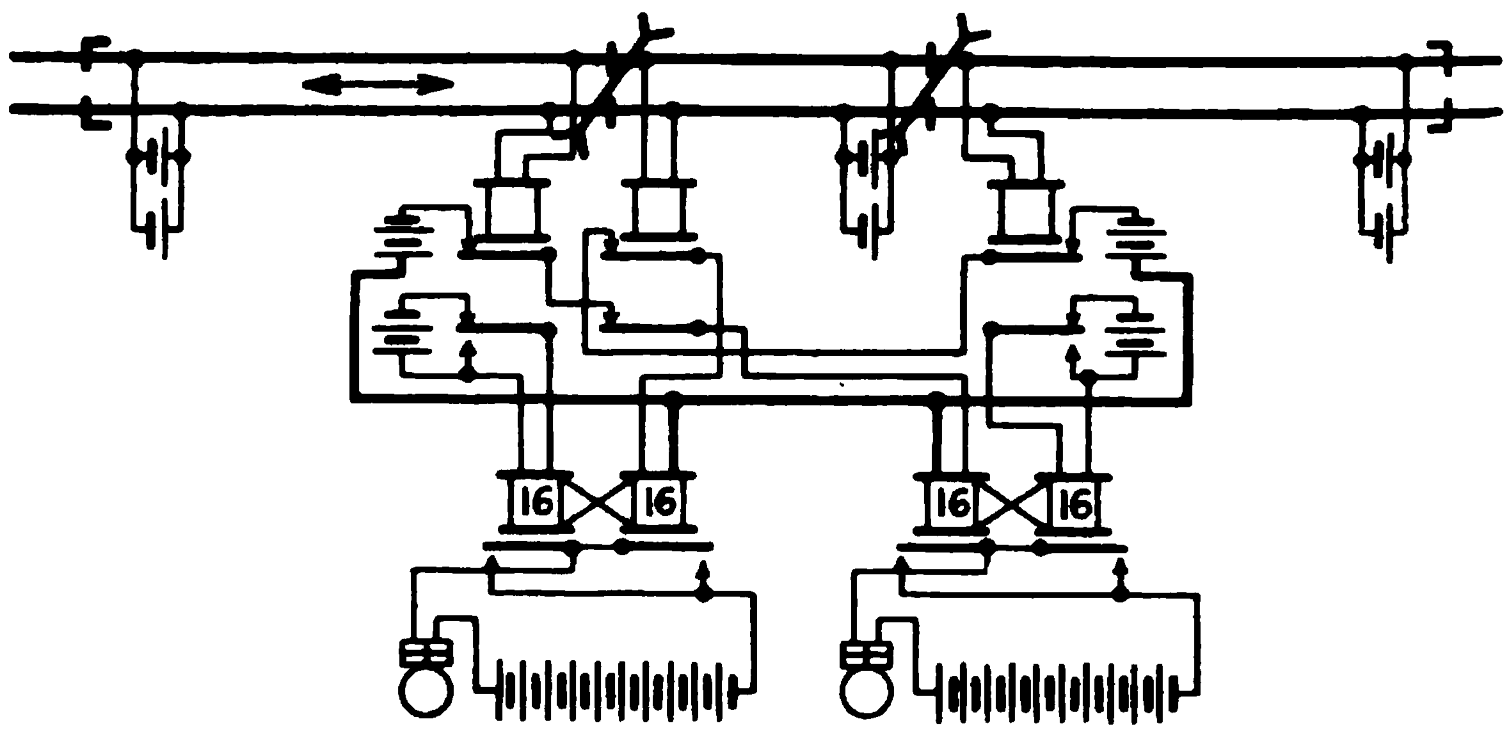


Fig. 106

Fig. 107. Resistances A and B are used to equalize the flow of current in the two branches of each circuit, as explained

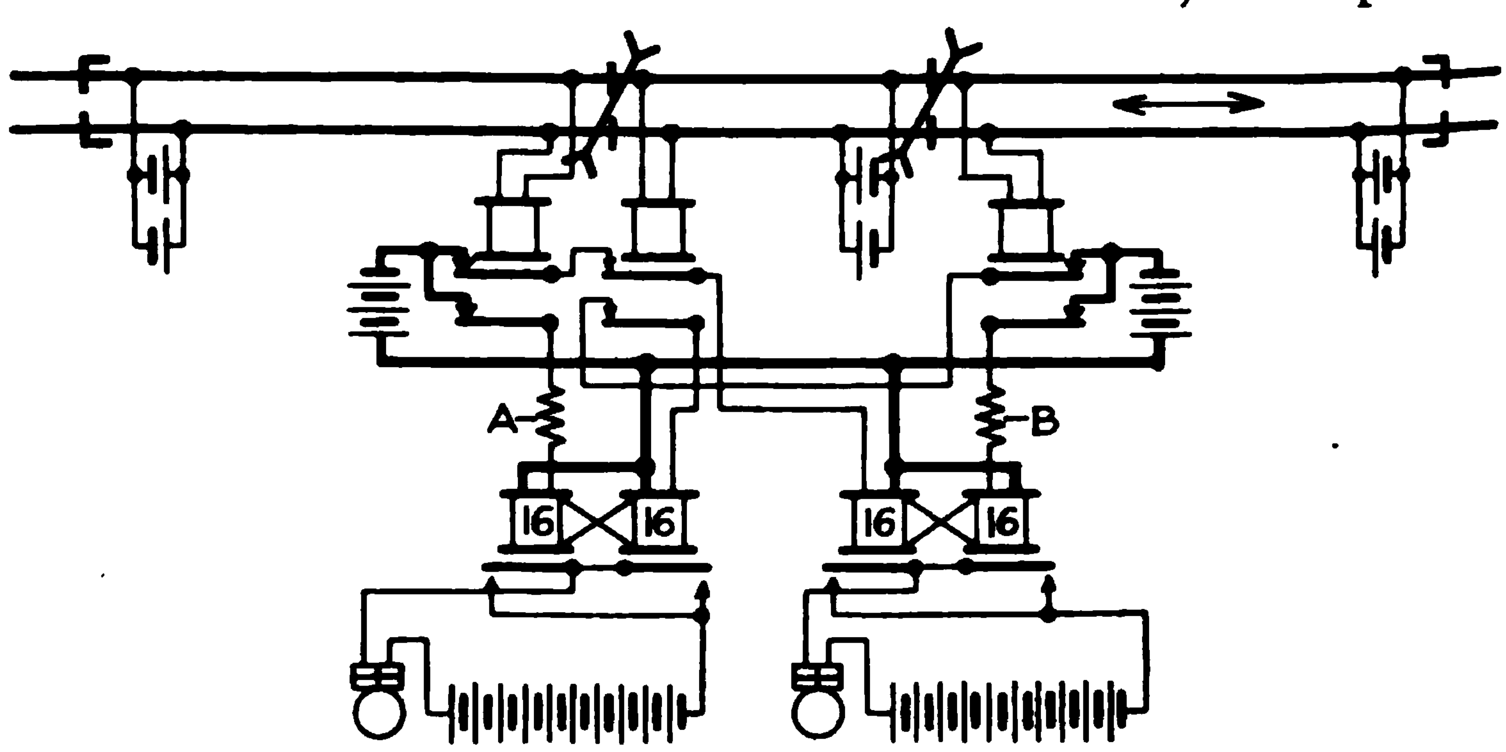


Fig. 107

in Art. 239, although in many cases they are unnecessary, on account of the short distance between the crossings.

This arrangement may be modified by employing higher resistance coils in the interlocking relays and using the bell batteries in a manner similar to that explained in Art. 238. In such an arrangement resistances A and B are of course unnecessary.

248. When interlocking relays provided with additional contacts are used at locations such as are shown in Figs. 106-107,

the arrangement illustrated in Fig. 108 is used, coils A and B being wound to a high resistance, or if it is desired to use a uniform resistance in the coils, gravity batteries would probably be used, connected as in Fig. 99.

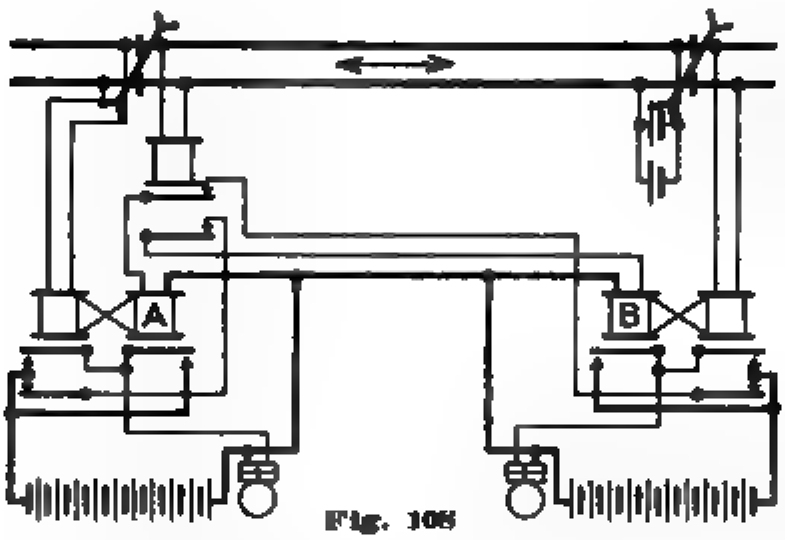


Fig. 108

249. A modification of this arrangement, in which one track relay is omitted, due to arranging the track battery as in Fig. 104, is illustrated in Fig. 109. Both bells are, in this instance, operated by the same battery and a break in any of the wires would result in stopping one of the bells. Therefore if line wires are employed, requiring lightning arresters, fuses should not be used.

Of course, if desired, the middle track circuit may be arranged as shown in Fig. 103.

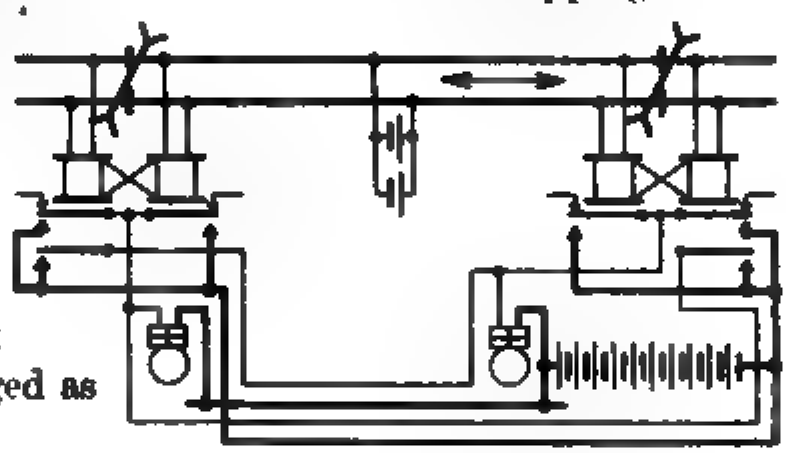


Fig. 109

250. Another method employed to cover the layout shown in Fig. 108, is illustrated in Fig. 110. It will be observed that the middle track circuit is controlled by magnet A, while the line circuit is controlled by magnets B and C.

The contact fingers which control *track* or *line* circuits, must be arranged as follows: The upper contact operated by magnet B must *open* whenever the armature is released; that is, whether

this magnet or magnet C is first de-energized. If this were not so arranged magnet D would pick up when an east-bound train passed off circuit C, thus stopping the bell at crossing Y too soon. The upper contact of magnet A must be arranged so that it will *not open* its front contact when de-energized, if magnet D is first de-energized. This is necessary in order that an east-bound train on circuit A, will not prevent the energizing of magnets B and D, thus causing the bell to continue ringing after the train passed the crossing. It is advisable to arrange the front contact on coil C so that it will close when energized, irrespective of the position of the armature of coil B. This is desirable on account of reverse movements, as explained in Art. 244.

Magnet D may, of course, if wound to the proper resistance, be operated by the bell battery at crossing X.

251. When two adjacent crossings are to be protected by alarms starting at different points, the arrangement shown in Fig. 111, may be used. An east-bound train starts the bell at crossing X, when it passes point A, and the bell at crossing Y, when it passes point B, each bell stopping as the rear of the train passes it.

As will be seen the circuits may be arranged, with suitable modifications, for additional crossings.

252. A method of operating crossing alarms at three adjacent crossings far enough apart to provide a ringing section between them, is shown in Fig. 112. This arrangement which employs two interlocking relays, may be used instead of modifications of the arrangements shown in Figs. 99-105, which require three interlocking relays.

A *bone point* is attached to one of the additional springs on each of the interlocking relays which is used to prevent the line circuit, that controls the bell at crossing Y, from closing for an out-going train: For instance, when an east-bound train enters circuit A, magnet A releases its armature, causing the bell at crossing X, to ring; as the train passes onto circuit B, the armature of magnet B is released and the two upper contacts

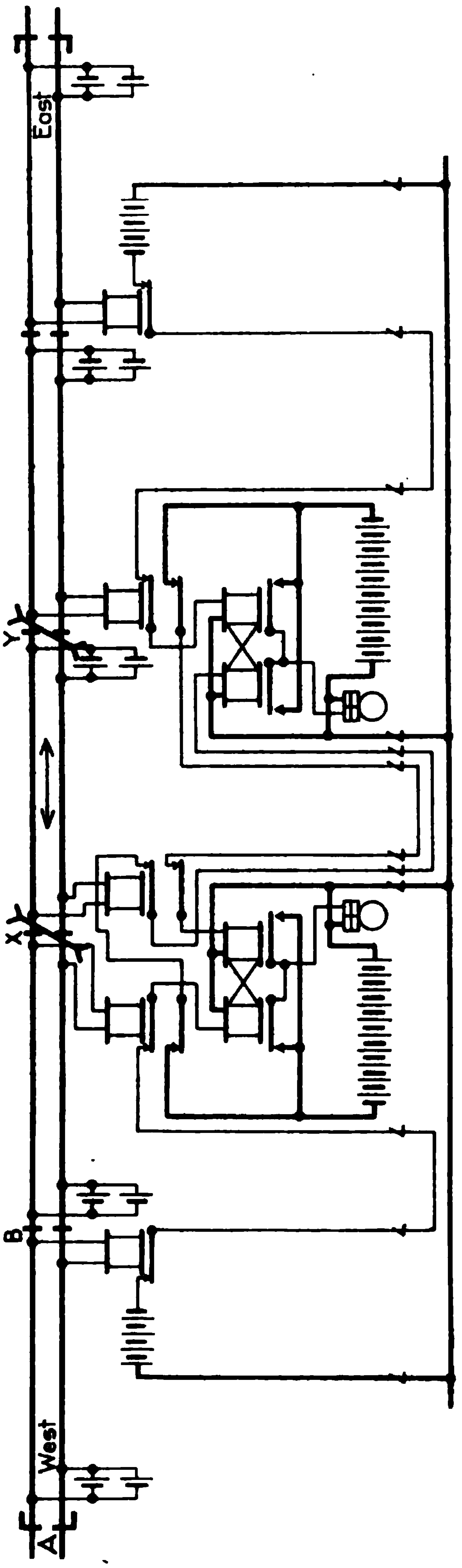


Fig. 111

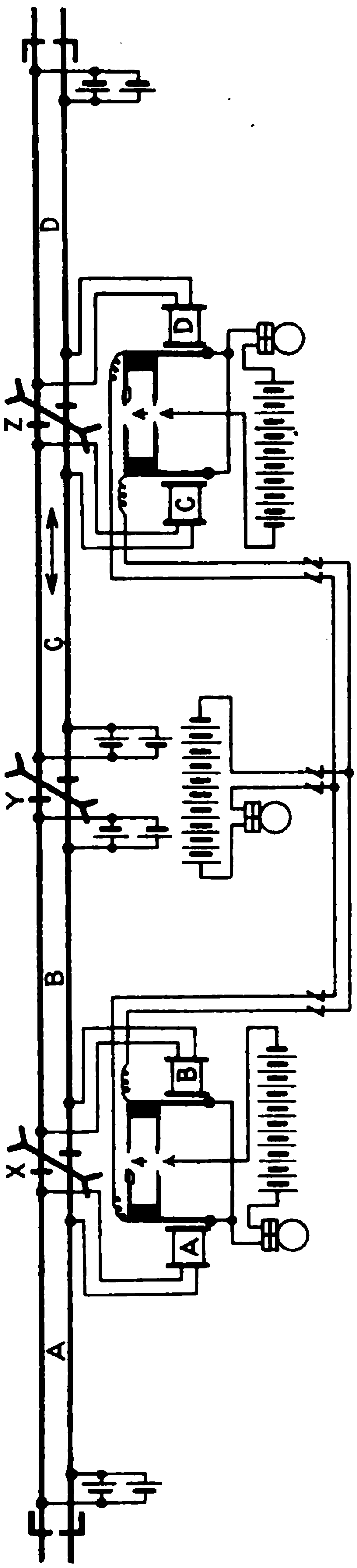


Fig. 112

on magnets A and B close the line circuit, thus ringing the bell at crossing Y; as the train enters circuit C, the alarm at crossing Z starts to operate and as the rear of the train leaves circuit B, relay A—B is restored to its normal position, thus opening the line circuit and stopping the alarm at crossing Y; when the train passes onto circuit D, the bone point on the upper contact of magnet D, drops *on top* of the upper contact on magnet C, thus *preventing* the closing of the line circuit and consequently the improper operation of the alarm at crossing Y.

253. It will be observed that the line circuit is normally open; this objection, however, may readily be overcome by altering the arrangement of the additional contacts so that they will operate normally closed and control a relay at crossing Y, which will operate the bell through a back contact.

254. The arrangement shown in Fig. 112 may be somewhat objectionable in that while cleaning or adjusting the contacts which control the line circuit and consequently the bell at crossing Y, the maintainer is a long distance from this crossing, and frequently being unable to hear the bell or to obtain a good view, cannot tell whether he is hindering traffic on the highway, while he is working upon the contacts. In addition, test keys cannot be arranged at crossing Y.

255. An arrangement for operating *overlapped* alarms at three adjacent crossings, is illustrated in Fig. 113. An eastbound train starts the bells at crossings X and Y, when it enters circuit A, and at crossing Z, when it enters circuit B, each bell stopping as the rear of the train passes it.

If interlocking relays having more than one contact on each side are not obtainable, ordinary relays may be installed on the two end circuits, in a manner similar to that explained in connection with Figs. 106-107.

256. When three crossings are located quite close together, it is sometimes desirable to start all of the alarms as the train enters the first track circuit. Circuits arranged to do this, are illustrated in Fig. 114.

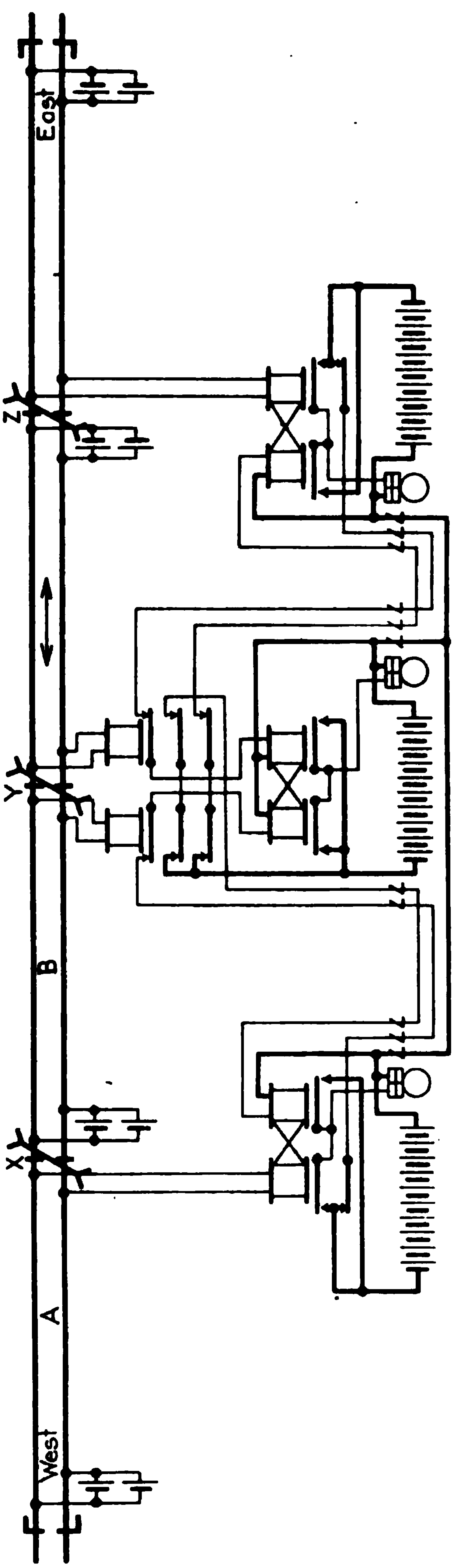


Fig. 113

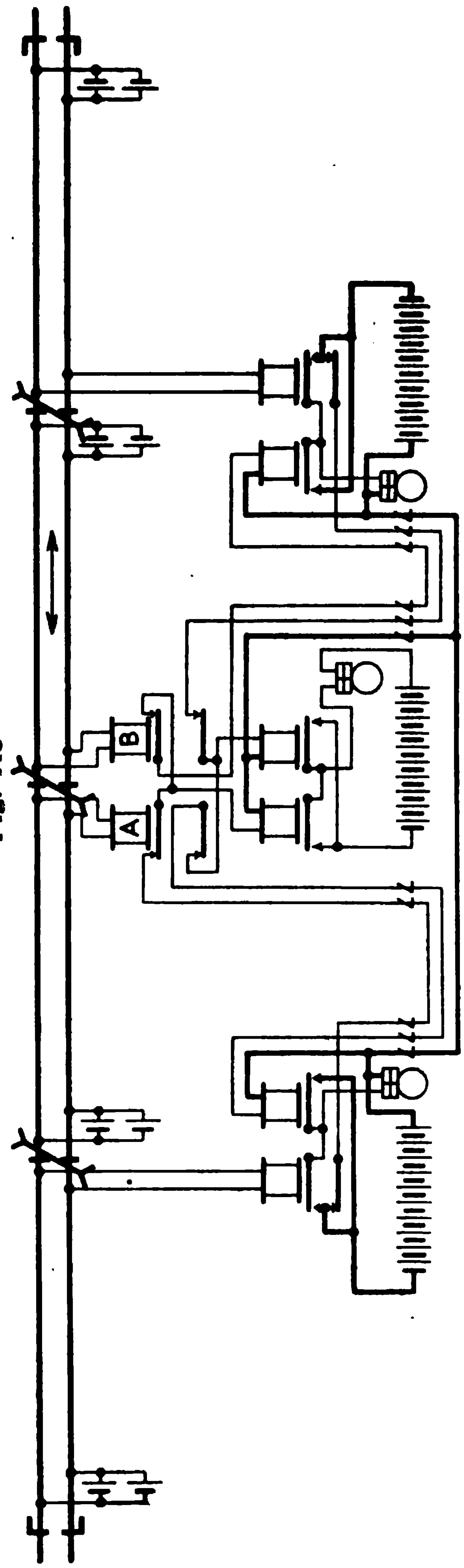


Fig. 114

When a train enters the first circuit, one side of each interlocking relay is de-energized, thus ringing all bells.

If interlocking relays with only one contact on each side are to be employed, the circuits may be modified as explained in connection with Fig. 113.

It will be noted that the circuits may be arranged satisfactorily if track relays A and B, are placed at the opposite end of the circuits; that is, if these circuits are arranged to feed *away* from the middle crossing, instead of *towards* it, as shown.

257. Another method of arranging the circuits for this layout, which may be considered as a development of those shown in Fig. 110, is illustrated in Fig. 115.

With this arrangement the front contacts which control *track* or *line* circuits, must be so adjusted that they will *not open* if, when released, the other armature in the same relay is down; and in addition the contacts operated by magnets A and B, must be so adjusted that they will *not close* when these magnets are energized, if the armature with which they interlock is down, being the last to release, while those operated by C and D must *close* under like conditions. If it is desired to have the alarm at crossing X operate for a train which has passed over the crossings and, having stopped in the last circuit, backs over crossing X, the upper contacts operated by magnets E and F must be adjusted the same as those operated by C and D.

258. An arrangement of circuits for the layout shown in Figs. 114-115, in which no line wires are used, is illustrated in Fig. 116. The magnets of the interlocking relay at the middle crossing are arranged as clearing relays, and the indication of the presence of a train is relayed from one track circuit to the other by shunting.

To insure that the bells will not continue to ring at crossings after the rear end of a train has passed them, the contacts which shunt the track circuits must be arranged the same as the contacts operating the bell circuits, that is, so they will *not* make contact if their armature releases last.

259. When signal apparatus foreign to the alarms is to be controlled over the same track, it is customary to accomplish

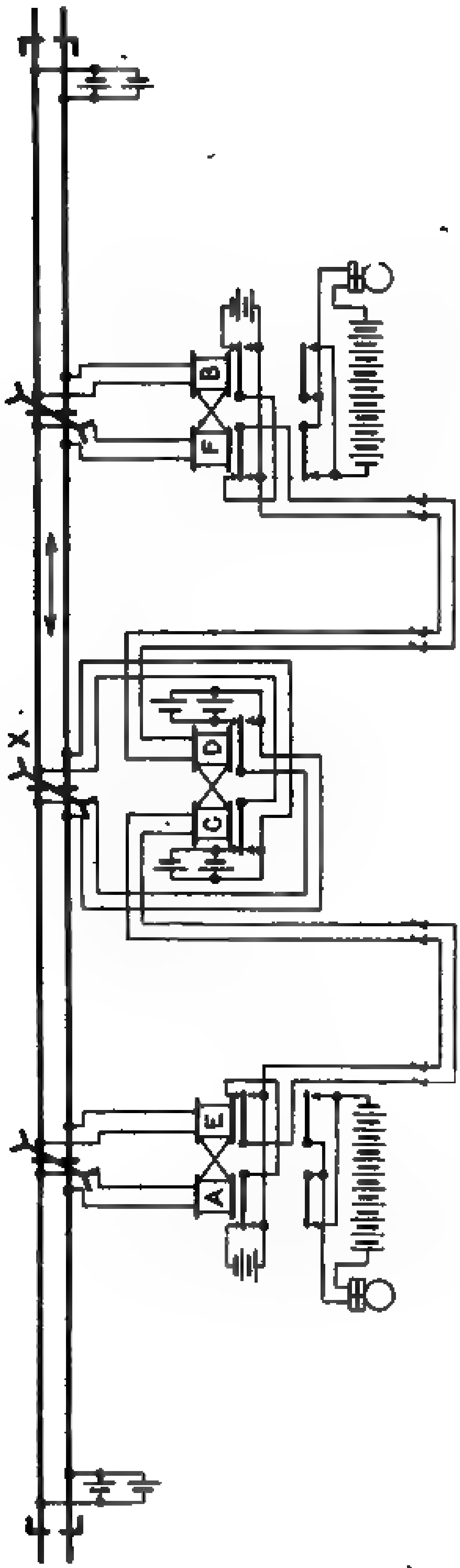


Fig. 115

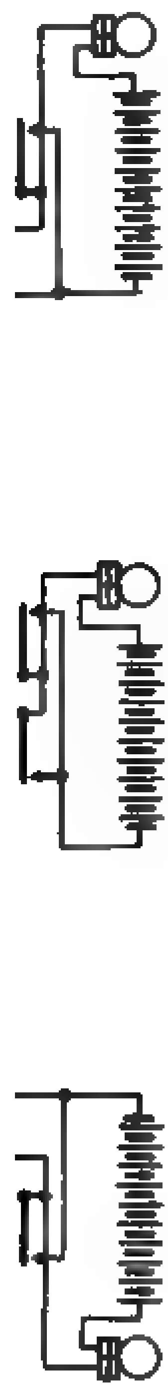


Fig. 116

the circuit for relay B, which when energized completes its stick circuit through its front contact and opens the stick circuit for

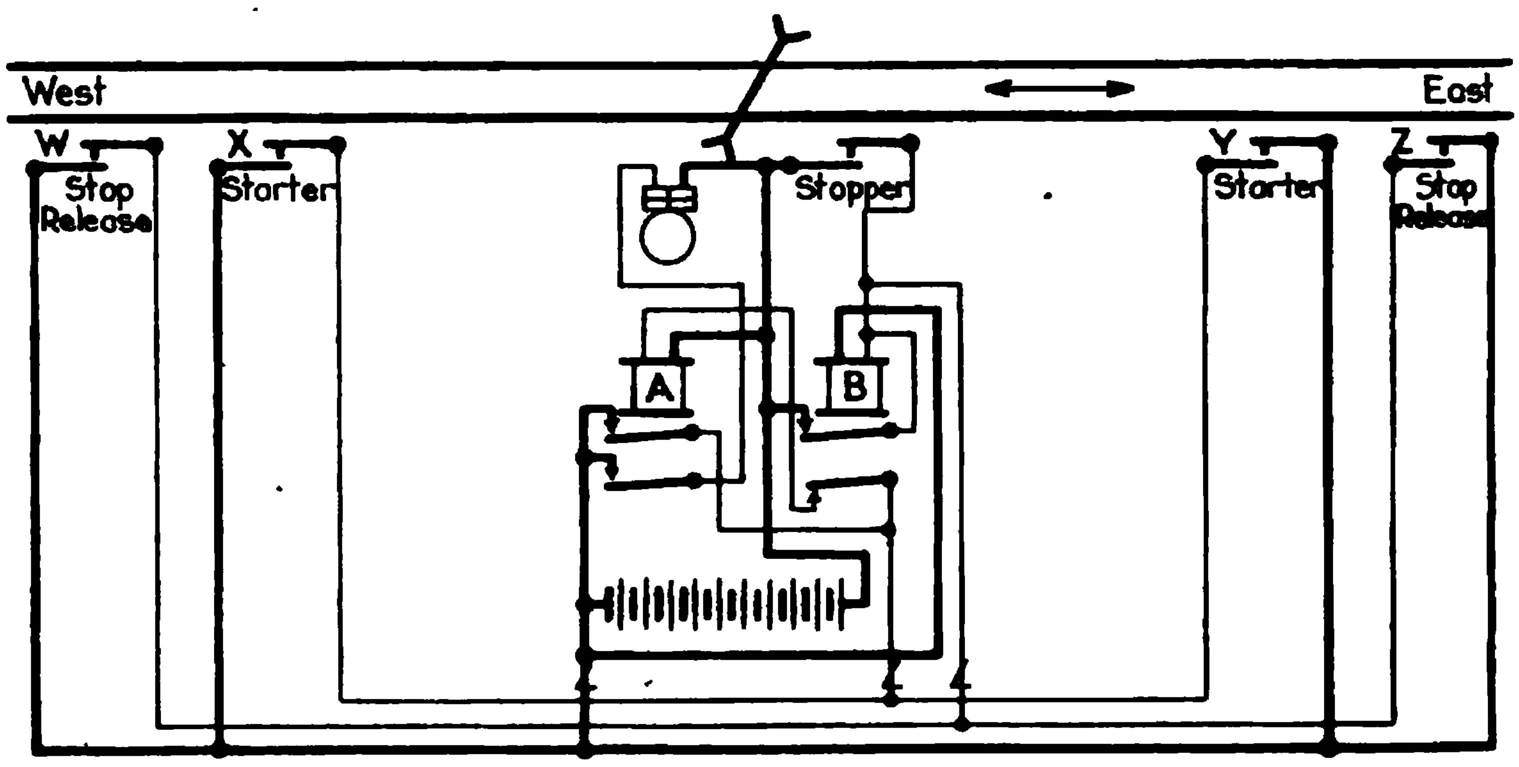


Fig. 119

relay A, at its back contact. When the train deflects starter Y, relay B keeps it from energizing relay A, and consequently the bell does not ring. The deflection of stop release Z, shunts relay B, causing it to assume its normal position.

263. The necessity for having the starter and stop release a maximum train length apart is apparent, when it is considered that if the head end of the train operates the stop release while the rear end is operating the starter, relay A would again be energized and the alarm operated indefinitely.

The resistance of relay B should be as high as possible so that it will easily be shunted when the stop releases are operated.

264. The arrangement illustrated in Fig. 119, is somewhat objectionable, in that a failure of either of the starting or stop releasing circuits, may result in the alarm failing to operate when a train approaches the crossing.

265. An arrangement employing normally closed instead of normally open line circuits, is illustrated in Fig. 120. The operation for an east-bound train is as follows: When the stop release W is deflected, it momentarily de-energizes relay C, but this has no effect on the other relays or the bell, as it simply breaks the circuit of relay B, which is already de-energized.

When the train operates starter X, the stick circuit for relay A is broken and the relay de-energized, thus closing the bell cir-

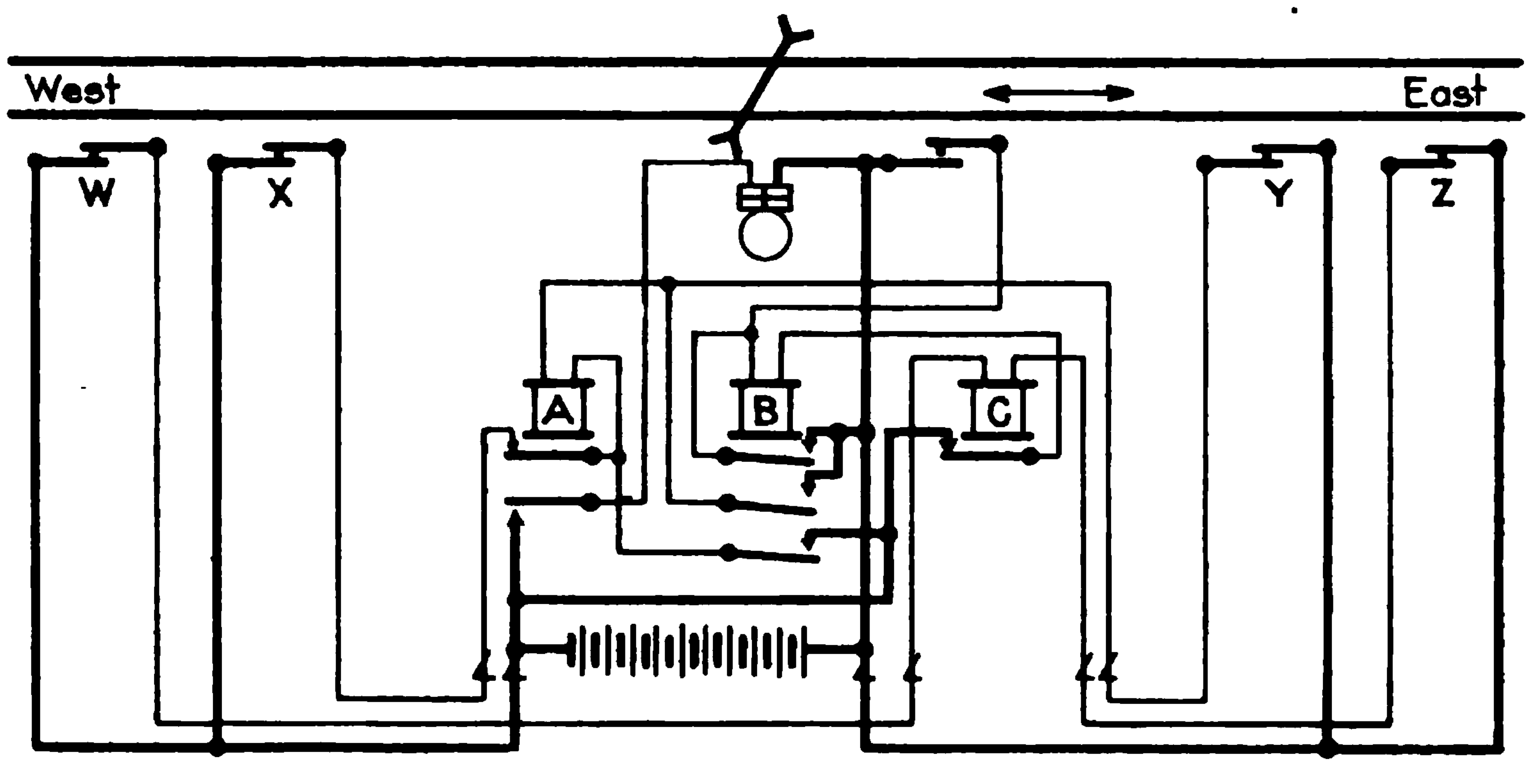


Fig. 120

cuit. When the train reaches the crossing it operates the stopper, closing a circuit for relay B, which when energized closes its stick circuit through the contact on relay C. As relay B is now energized, a circuit for relay A is closed through its two lower contacts, and therefore this relay attracts its armature, breaking the bell circuit and again completing its stick circuit through the starters. When the train deflects starter Y, relay A will not be affected, as its circuit is closed through contacts on relay B. The stop release Z, being deflected by the train, momentarily breaks the circuit for relay C, which in turn breaks the stick circuit for relay B, thus restoring all instruments to their normal position.

266. In cases where a switch occurs between the starter and the crossing, an *additional stopper* may be installed to operate when a train enters the siding, in a manner similar to that employed in *double track arrangements*.

A train entering such a siding after passing the crossing, would leave relay B, Figs. 119-120, energized, but as another approaching train operates a stop release before it operates a starter, this relay would be restored to its normal position before it could interfere with the proper operation of the alarm.

The additional stopper may, however, be undesirable at meeting points, where it would be operated by a train entering the

siding to allow another train to pass, after the latter had passed the stop release, as in such a case the alarm would fail to operate for the train approaching the crossing.

267. Time Circuit Controllers: An arrangement of circuits for operating a single track crossing alarm, is illustrated in Fig. 121. As will be observed, this is a development of Fig. 71,

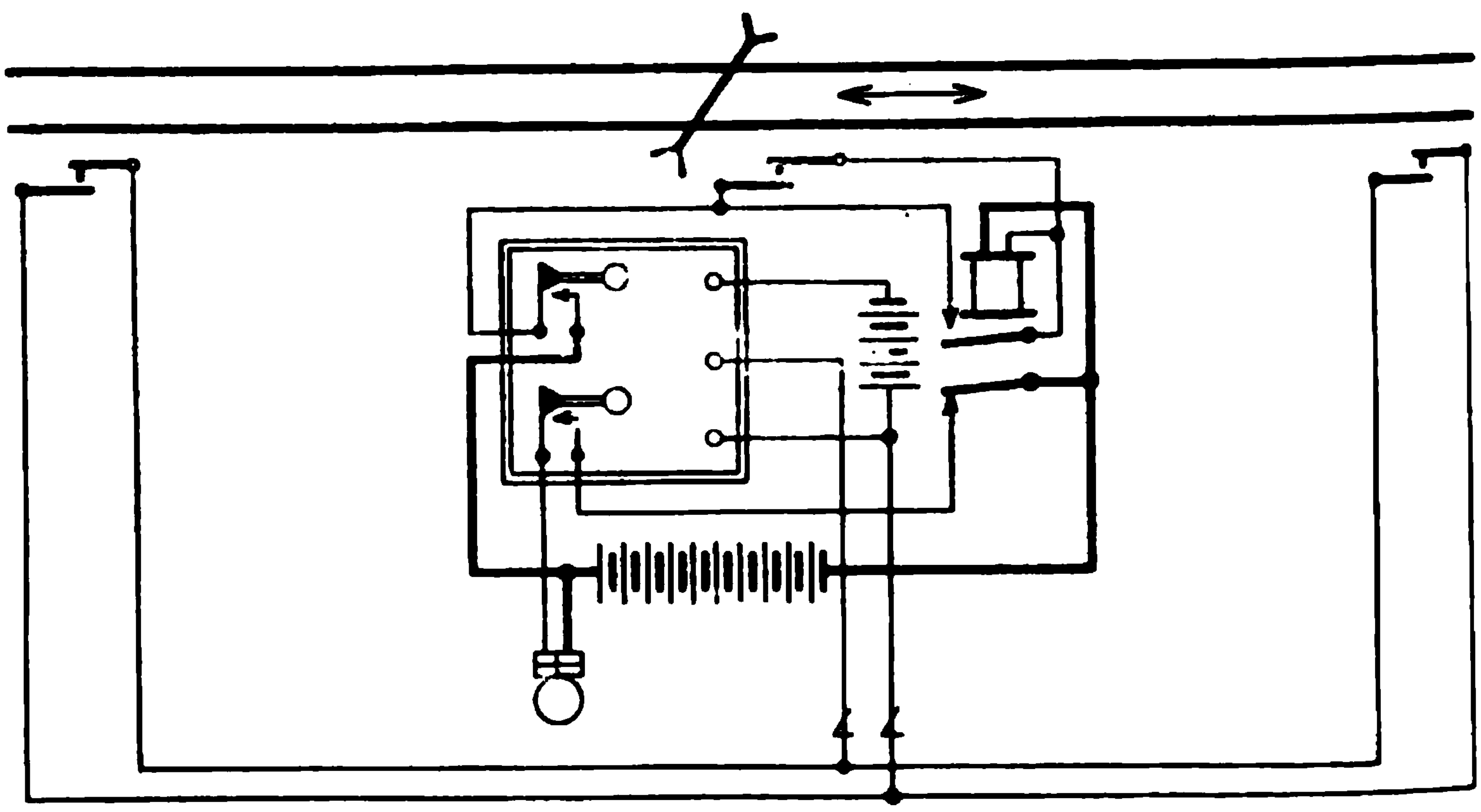


Fig. 121

an *additional starter* being added, so that the time circuit breaker will be put in operation by a train approaching from *either* direction.

The time circuit breaker is so adjusted that it will continue to operate during the time required for a train to run from one starter completely past the other, this being necessary in order that the starter at the outgoing end will not cause this instrument to go through a second operation and thus give a false alarm.

Short track circuits may of course, be substituted for the track instruments.

268. Another arrangement for using the time circuit breaker is shown in Fig. 122, in which short track circuits are employed, with normally de-energized interlocking relays at each starting point. These relays are provided with bone points which allow them to close the line circuit for a train approaching the crossing but not for a train leaving it. Thus an outgoing train is prevented from starting the time circuit breaker.

If desired, the stick relay shown in Fig. 121, operated either by a track instrument or short track circuit, may be installed

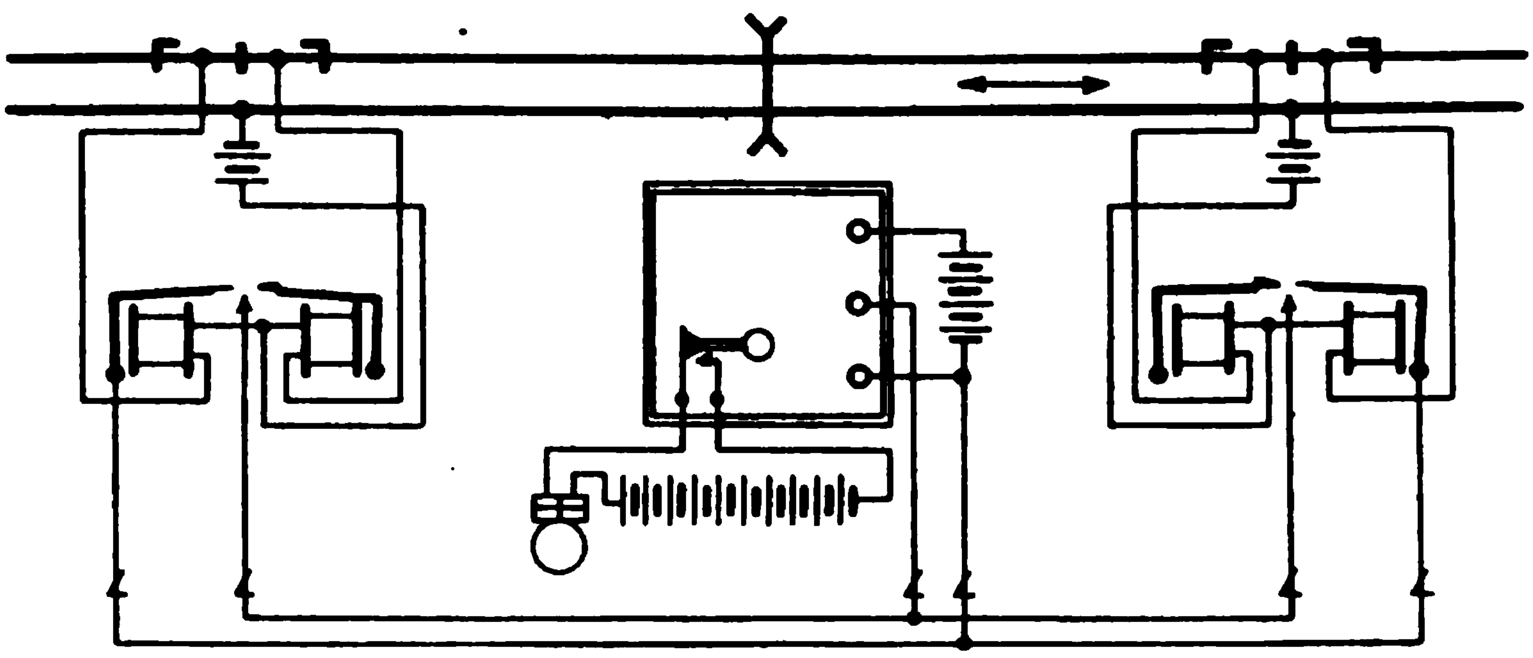


Fig. 122

in connection with this arrangement, in order to stop the alarm as soon as the train reaches the crossing.

269. Interrupting Devices: It will be observed that with the arrangement shown in Fig. 98, the alarm is stopped as soon as the first pair of wheels passes the joints at the crossing, after which the train may leave cars standing on either or both sides of it, or make switching movements over the crossing in either direction, without again ringing the bell, unless it entirely clears both circuits.

270. A method of applying stopping and starting keys to this arrangement, is illustrated in Fig. 123. It will be observed that the starting key Y can be used to start the alarm after the train has stopped it; for instance, if a train should cut apart, leaving the rear portion on the approaching circuit, and pass over the crossing to do switching, etc., it may be desirable to have the alarm operate, after it has again coupled up and is approaching the crossing.

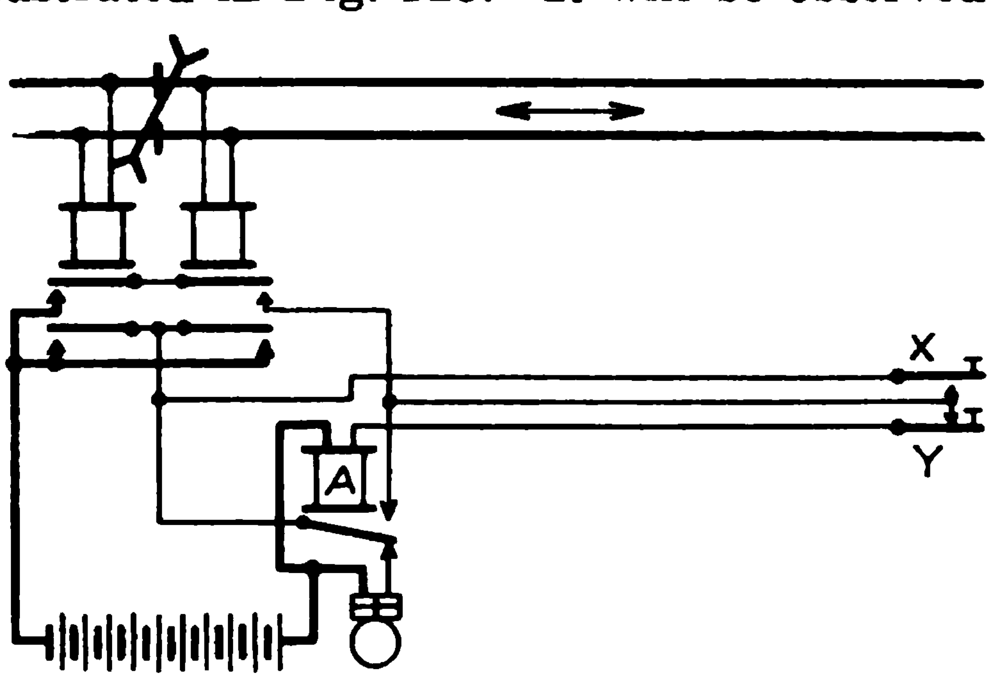


Fig. 123

This key will also break the stick circuit and allow the alarm to operate for a following train that may have entered the approaching circuit just before the first train passed out of the other circuit, it being necessary to operate the key directly after the latter train has passed off the circuit.

271. If it is desired to start the alarm while both circuits are occupied, an additional stick relay and key are installed, being connected as shown in Fig. 124. In this case keys X and Y perform the same function as the two keys in Fig. 123. Stick relay B, which closes a circuit for the bell through its lower contact is operated by the additional key Z, and completes its stick circuit through a lower contact on relay A; therefore when there is a train on each circuit and the bell is not operating, due to relay A being energized, it is started, when desired, by operating key Z.

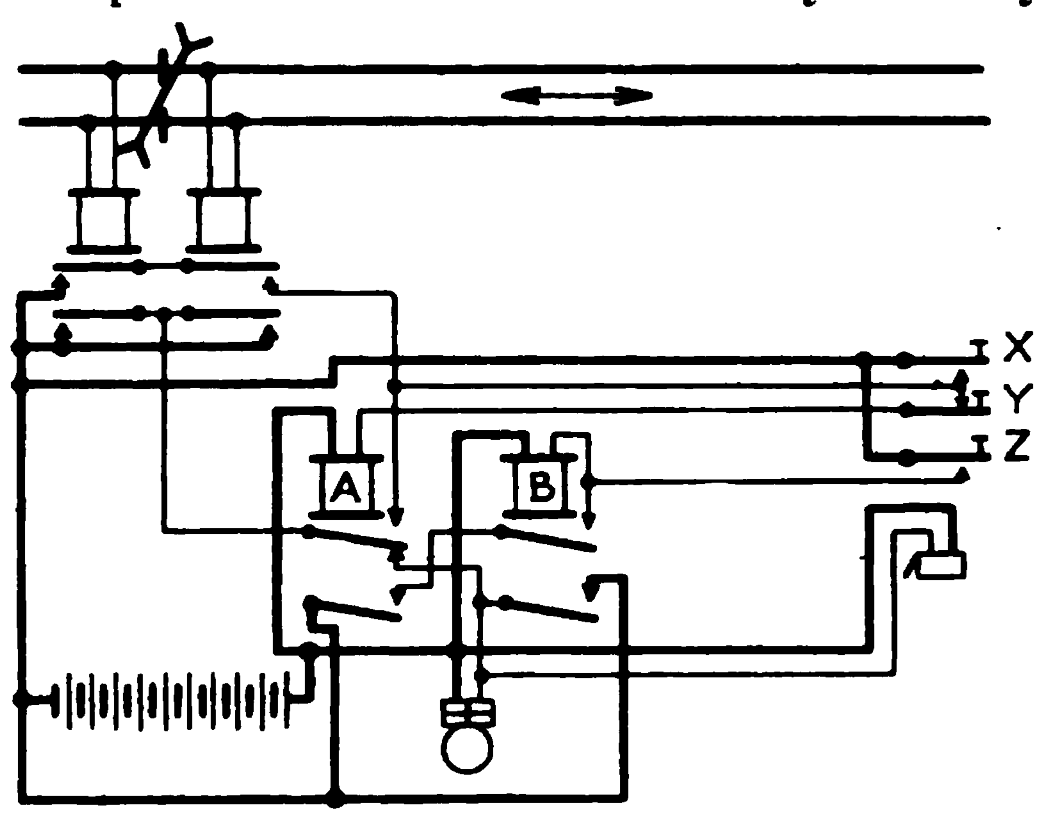


Fig. 124

As relay A is de-energized whenever key Y is operated, thus breaking the stick circuit for relay B, it is evident that this key will act as a stopper if both track circuits are occupied and the bell has been started by key Z.

If the keys are at such a distance from the crossing that the bell cannot be heard plainly, it is desirable, especially with this arrangement which employs two starters, to install a small bell or buzzer near them, as shown.

Of course if desired, relay B and key Z may be installed without keys X and Y.

272. Another arrangement is illustrated in Fig. 125, which may be used under circumstances similar to those described in

Art. 269. In this case, the bell circuit is carried through front contacts on each side of the interlocking relay, these contacts

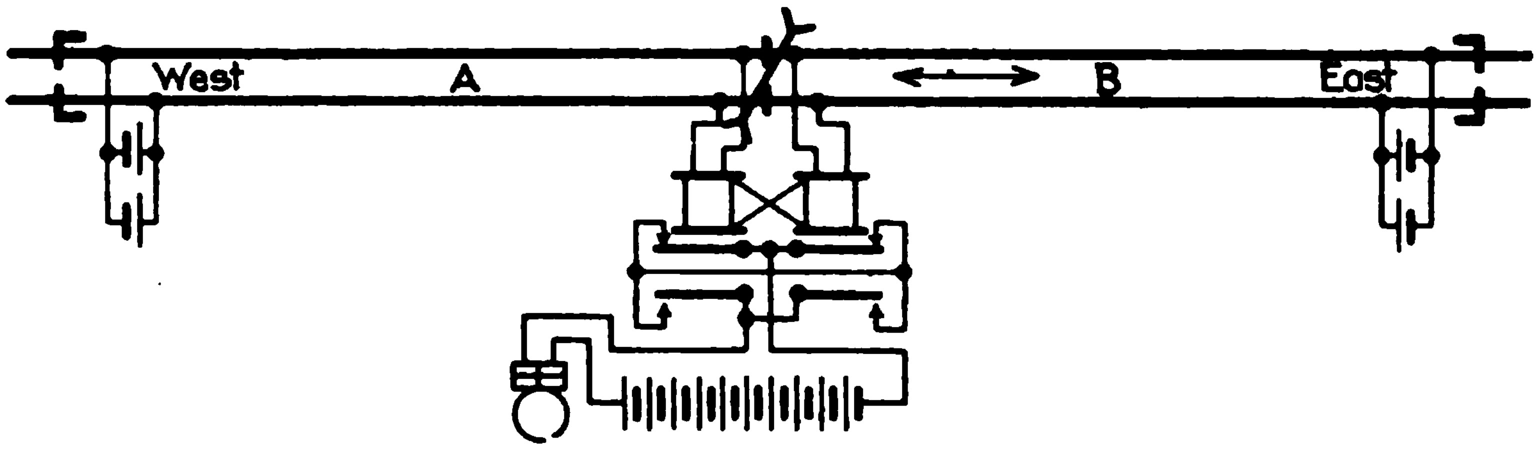


Fig. 125

being connected in multiple, and arranged to open whenever their armature is released. Thus the bell circuit is broken when both magnets are de-energized.

It will be seen that an east-bound train may leave part of its cars on circuit A, and switch or do other work on circuit B, without ringing the bell, but when it returns for the cars on A, and passes entirely off B, the alarm will again operate, thus giving an indication, which is desirable in case the train again moves over the crossing. With the arrangement shown in Fig. 98, the bell remains silent under like conditions.

With both of the arrangements, a following train will be prevented from giving an alarm while the first train is in the outgoing circuit, but with the arrangement shown in Fig. 125, the bell will again start when the rear of the leading train clears this circuit.

273. At points where trains are required to stop close to the crossing, for instance, at a passenger station which is adjacent to the highway, it is sometimes desirable to automatically stop the alarm, so that it will not continue to ring when the train is standing at the station. An arrangement of circuits to cover such a condition, is illustrated in Fig. 126. As will be seen, this is an application of Fig. 74, and may be varied as shown in Fig. 75.

The short circuits are made only long enough to avoid their

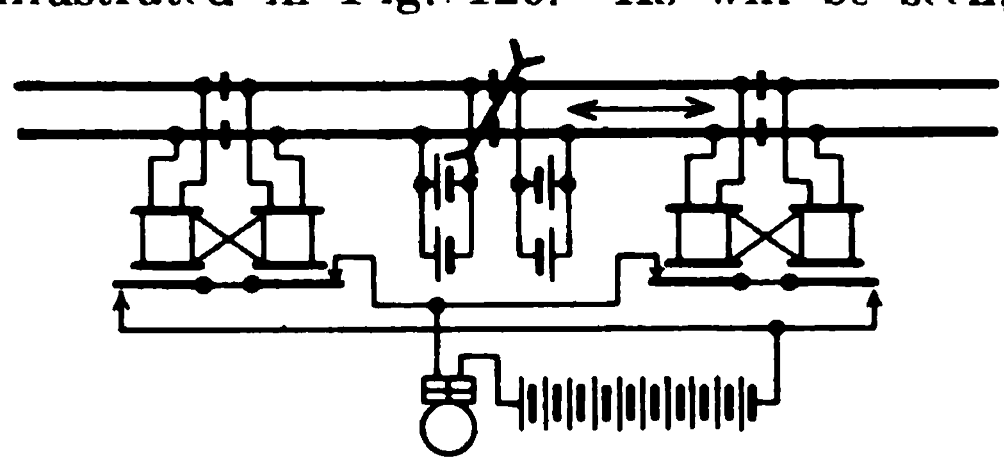


Fig. 126

being spanned by a car, for if spanned the alarm would again operate.

This arrangement will allow the alarm to operate for a following train as soon as the first train has cleared the first short track circuit.

274. The stick relay and key arrangements illustrated in Figs. 77-82, also the time circuit breaker arrangement shown in Fig. 83, may be applied to single track alarm circuits.

When convenient it is usually desirable to arrange these devices to cut out the alarm for trains in one direction only, allowing it to operate for trains in the opposite direction as usual, although in some instances, where trains frequently stand on either side of the crossing, it may be more satisfactory for the key to cut out the bell for movements in both directions.

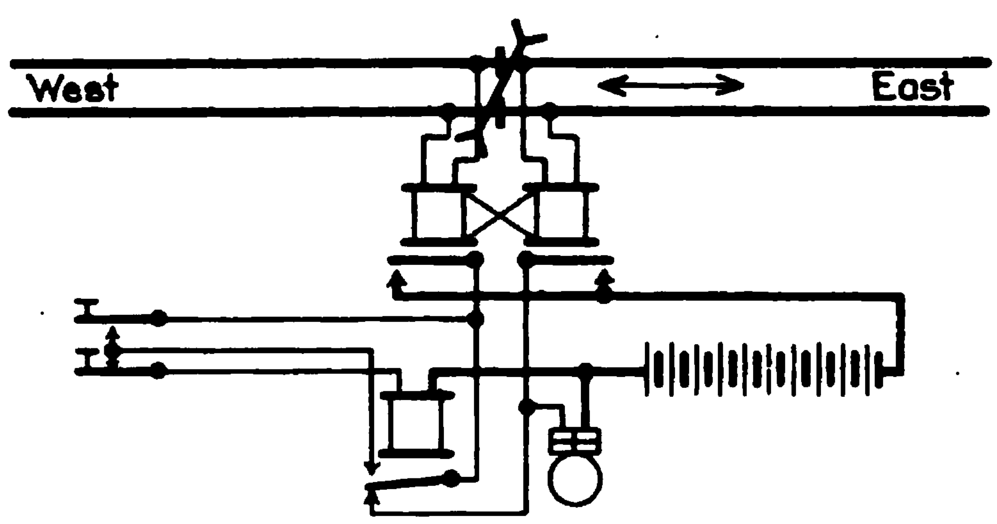


Fig. 127

275. Illustrations of such arrangements are given in Figs. 127-128, which show the application of stick relays and keys to the circuits shown in Fig. 92. In Fig. 127, these devices are arranged to operate for east-bound trains only, and in Fig. 128, for movements in both directions. Of course, in Fig. 127, another stick relay and its keys could be installed to operate independently for west-bound trains, which would probably be desirable in case the keys were located at a distance from the crossing; that is, when, as frequently happens, the keys for east-bound trains are placed west of the crossing, and those for west-bound trains, east of it.

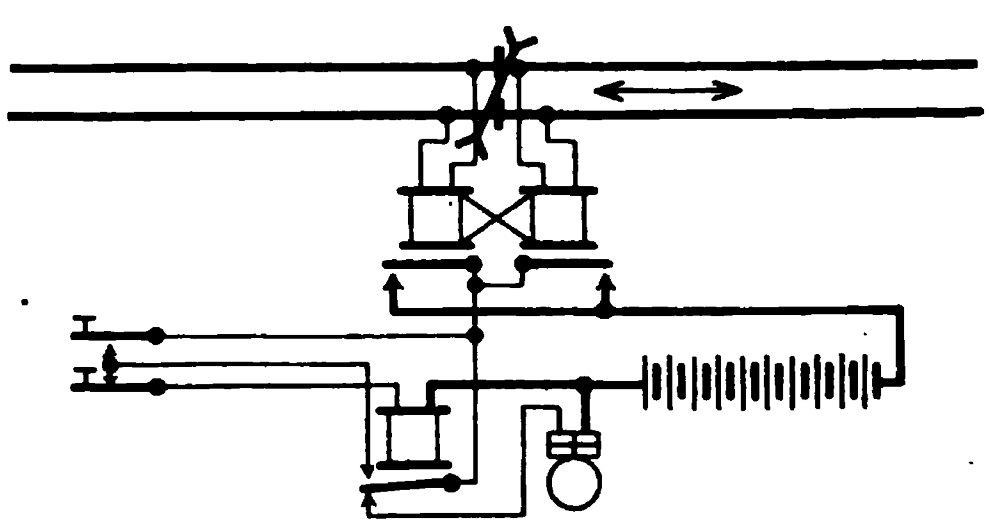


Fig. 128

276. In case a low resistance stick relay is used, making it undesirable to use the main battery to operate it, additional contacts on the interlocking relay should be provided. Such an arrangement, which, it will be observed, is an application of that shown in Fig. 78, is illustrated in Fig. 129, this arrangement accomplishing the same results as that shown in Fig. 128.

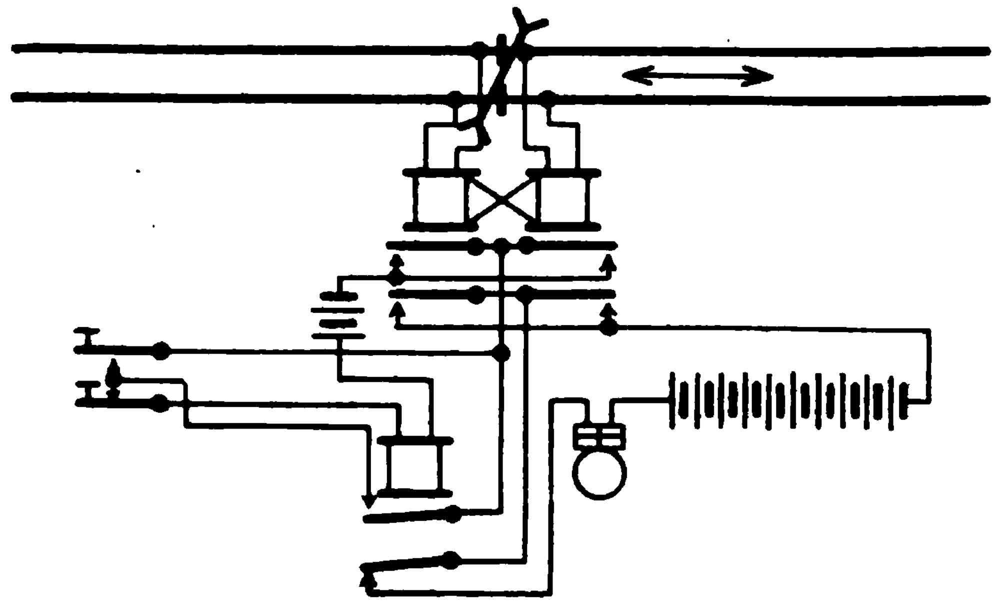


Fig. 129

277. If it is desired to install keys with the circuits shown in Fig. 97, it may be done without the use of an additional relay, in the manner shown in Fig. 130, key X being used to stop the alarm and key Y to start it. If the keys are near the crossing this arrangement will work satisfactorily, but if very far away, the resistance of the wires is likely to interfere as the voltage on the stick relay circuit cannot be increased to any great extent, on account of its connection with the track.

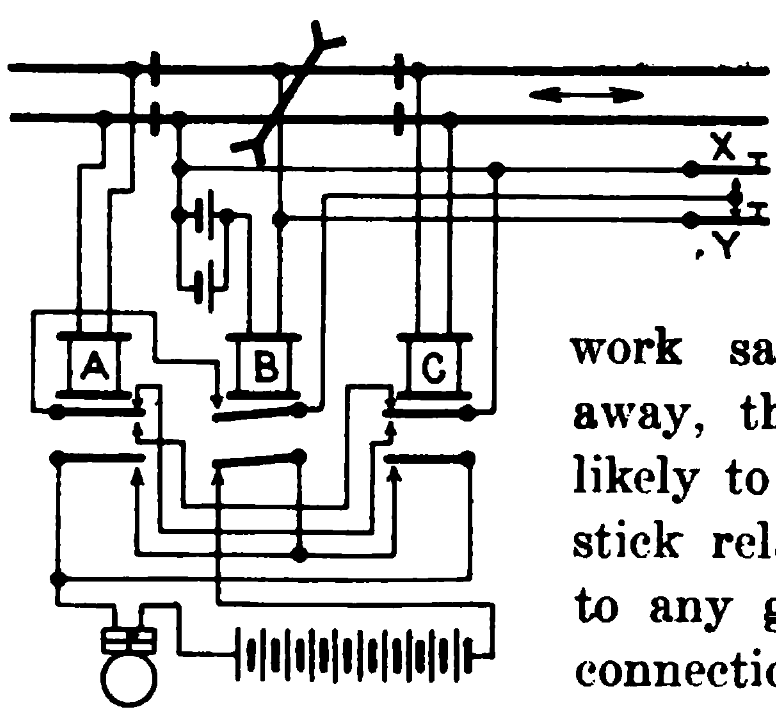


Fig. 130

278. Annunciators: An arrangement of annunciator circuits for single track is illustrated in Fig. 131, this being an application of the circuits shown in Fig. 85.

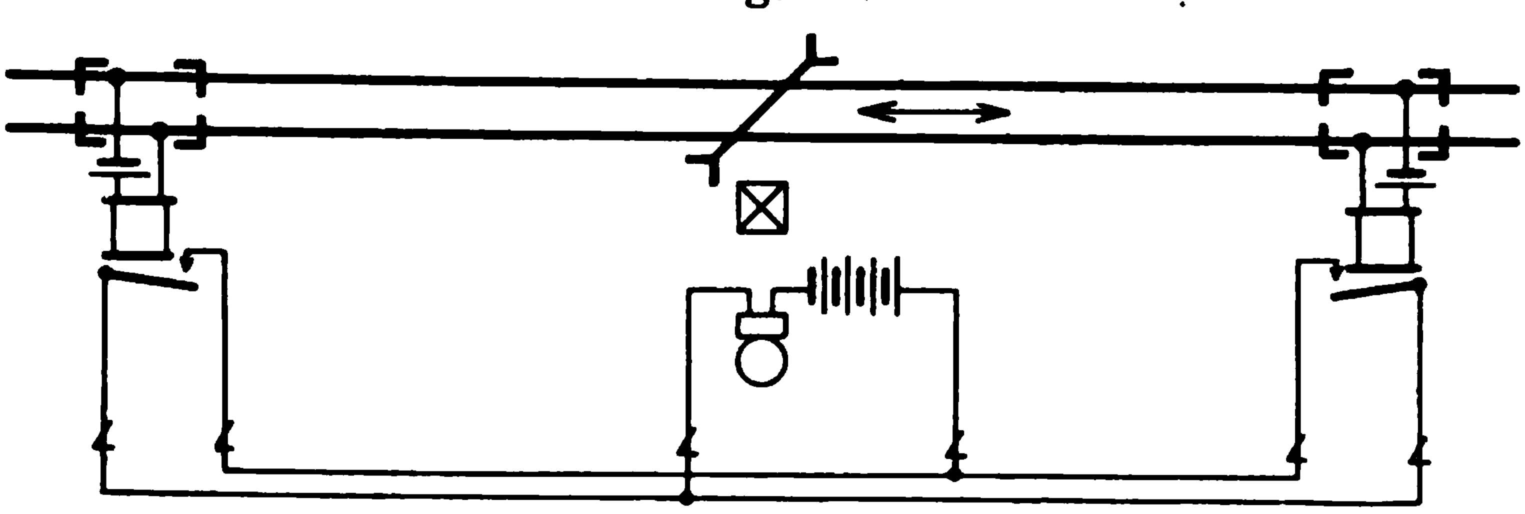


Fig. 131

The bell will ring for outgoing trains in each direction but this is not usually considered a serious objection. However, if it is desired to avoid this, the arrangement of interlocking relays shown in Fig. 122, may be employed.

Any of the annunciator circuits described for *double track*, may be applied in a similar manner.

EXAMINATION QUESTIONS

(1) Describe the operation of the interlocking relay in Fig. 92, for a west-bound train, stating the effect produced on the bell.

(2) If a west-bound train enters circuit B, Fig. 92, while an east-bound train, which is moving into the siding to allow the former train to pass, still shunts this circuit, what dangerous condition would result?

(3) What would be the probable effect, if exceptionally high resistance developed in the back contact of coil A, Fig. 92?

(4) What would be the result of a failure of battery C, Fig. 93?

(5) If an east-bound train on the main line, Fig. 96, moves onto circuit A and then backs over the branch, when will the alarm at crossing Y commence to operate?

(6) What would be the effect of a failure of the battery for relay B, Fig. 97?

(7) In Fig. 98, what would be the effect, if the wire leading from the front contact of relay A, became disconnected?

(8) (*a*) If coil D, Fig. 99, is wound to a resistance of 9 ohms and the wiring between the coil and the battery has a resistance of 3 ohms, what will be the voltage of the battery, if the operating voltage of this coil is 0.8 volt and 5 per cent. above the working voltage of the circuit, is allowed to cover contact resistance, etc.? A multiple arrangement of gravity battery is to be used in which it is assumed that each cell will have an internal resistance of 3 ohms and an effective E. M. F. of 1 volt. (*b*) How much does

the voltage supplied exceed that actually required, plus the 5 per cent. margin?

(9) (*a*) What portion of the wiring shown by heavy lines in Fig. 98, is actually a common wire? (*b*) What portion in Fig. 106?

(10) If a west-bound train, after passing over crossings Z and Y, onto circuit B, Fig. 113, should back over these crossings, would the alarm for crossing Z operate before the train reached this crossing?

(11) At what point would the common wire have to break in Fig. 113, to cause the alarms at all the crossings, to operate continuously?

(12) What would be the effect of a west-bound train operating stop release W, Fig. 119, before passing off starter X?

(13) If an east-bound train passed over track instruments W and X, Fig. 119, but instead of proceeding over the crossing, backs over these instruments, what would be the result?

(14) In Fig. 120, what would be the result of a break in the wire leading to a stop release?

(15) In Fig. 120, describe the operation of the alarm for an east-bound train assuming that the line wire to starter X is broken.

INSTALLATION AND MAINTENANCE

BELL POSTS AND SIGNS

279. Location: The location of bell posts is determined largely by local conditions. The post should be set as close to the track as practicable, in order that the bell may easily be heard on both sides of it. A minimum clearance of 7 ft. from the nearest rail is usually allowed.

280. If the highway is at right angles, or nearly so, to the track, either of the corners generally provide a satisfactory location. If, however, the highway crosses the track at an oblique angle, it is usually best to place the post in one of the *obtuse* angles, so that it will be as near the center of the crossing as possible.

281. When two bells are provided as mentioned in Art. 94, they would ordinarily be placed in opposite corners of the crossing, being located in the *acute* angles, where the highway crosses the track obliquely.

282. The grade of the highway sometimes determines the location of the post, it being considered desirable to place it on the up-hill side of the track, in order to favor down-hill traffic.

If there is a siding on one side of the main track, it is usually considered desirable to locate the bell next to the latter.

The location of the battery house (when used) or the pole line on which the signal wires are run, will sometimes become a governing factor, the alarm being placed on the same side of the track as the pole line, in order to avoid carrying line circuits across it.

When there is a battery shelter at the foot of the bell post, a good location for it, may govern to some extent, the placing of the post.

283. If there is a sidewalk on the highway, it is customary to set the post between the walk and the curb, but if not, it should be set near the driveway.

284. The bell is often mounted on the regular sign post mentioned in Art. 2, and occasionally on buildings or other structures, when conveniently situated.

285. Preparing and Setting the Posts: When bell posts are made of iron, or of wood, and are fitted with a sign, they are usually received ready to install, but if simply a wooden post without a sign is employed, it must often be prepared on the ground, as they are frequently rough when received. One method of finishing an 18 ft. post is illustrated in Fig. 132, sketch A showing the arrangement of the top of the post when the electric lamp, Fig. 16, is used. The spider may of course, be omitted, if the nature of the ground does not require it.

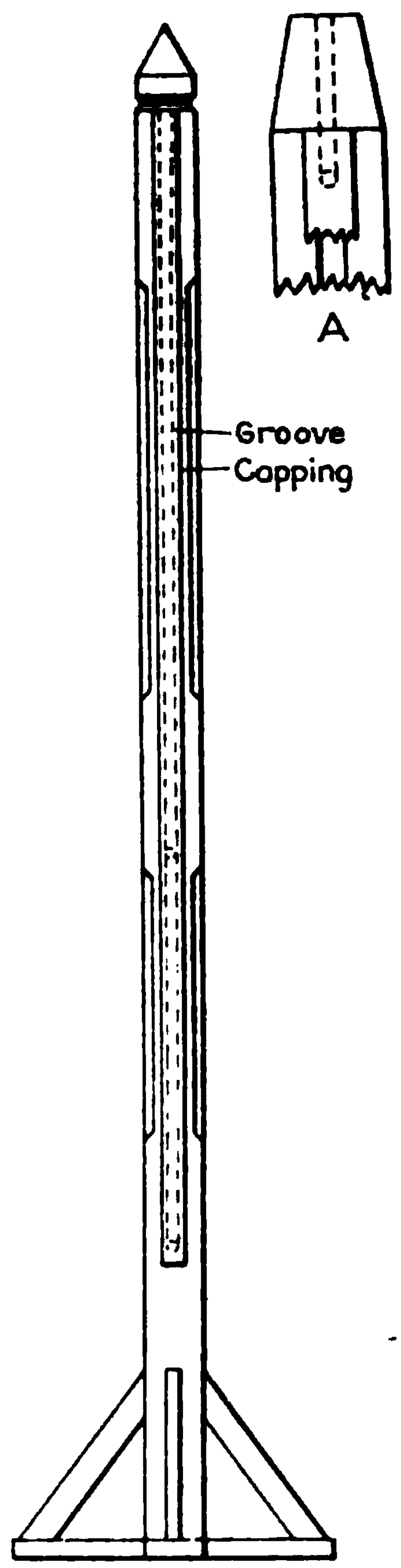


Fig. 132

That portion of the post which extends into the ground may be coated with preserving paint or otherwise treated to prevent rotting.* Of course, after the post is erected it should be painted. Iron posts are frequently painted black with white letters and wooden posts, white with black letters, although the colors used are frequently governed by standard practice.

286. When a bell post with no spider or other lateral projections is to be installed, a post hole auger may often be employed to advantage.

When using a spider the post should be plumbed before much earth is replaced in the hole.

*See treatment of poles in **Line Construction.**

TRACK CIRCUITS

287. When determining the limits of track circuits which govern a crossing alarm, there is frequently considerable freedom of choice as regards the location of insulated joints, this being especially true in cases where no apparatus foreign to the alarm is controlled by the same track circuits.

When the circuits are arranged so that the alarm stops when the *rear end* of a train passes the crossing, it is well to locate the joints, at the crossing, as nearly opposite the bell post as possible, so that the maintainer when riding upon the rear end of a train, will be able to observe whether or not the bell is operating properly.

At the ends of the circuits away from the crossing, a good location for the battery or relay shelter, will sometimes govern the placing of the insulated joints.

288. As the track circuits employed in this class of work are not intended to indicate whether the track is clear for traffic or not, fouling protection is usually not desirable. Fouling sections would, in many cases, simply prolong false ringing, for instance, when a train enters a siding before reaching the crossing. In other cases, the tendency to prevent a warning being given, by keeping the relay locked, for example when a west-bound train, Fig. 92, is leaving the siding before an east-bound train has passed off the circuit, would be increased.

Also, as crossing alarms are not intended to detect broken rails, it is customary not to especially provide for such a condition. On this account cut-outs at switches may usually be employed satisfactorily instead of insulating the switch rods.

289. The following table will be found convenient when determining the length of track circuits to be used with crossing alarms, annunciators, etc., to cover various traffic requirements. It will also be of value when locating track instruments and setting time circuit controllers.

TIME REQUIRED TO RUN A GIVEN DISTANCE AT A CERTAIN SPEED

Speed in Miles Per Hour	Feet Per Second	Seconds to run 1,500 Ft.	Seconds to run 2,000 Ft.	Seconds to run ½ Mile
10	14.7	102	136	180
20	29.3	51	68	90
30	44	34	45	60
40	58.7	26	34	45
50	73.3	20	27	36
60	88	17	23	30
70	102.7	15	19	26
80	117.3	13	17	22

BATTERY SHELTERS*

290. Battery Houses: These may be built on the ground, but are frequently made in the shop, the latter method generally being less expensive. It is not customary to paint them inside.

291. *Location.* To avoid disputes it is usually advisable to place the battery house on land belonging to the railroad company, although this may, in some instances, necessitate the use of additional wire and trunking.

These buildings, if possible, should not be placed within 10 ft. of the nearest rail and if convenient a greater distance is sometimes desirable, especially from a main track where high speed trains pass.

A good clearance is desirable in cold climates to avoid having the building damaged by snow thrown from plows.

It is customary to have the door face the track and if, as often happens, there is a ditch alongside of the track, the battery house should be placed back from it a distance sufficient to provide a good footing. If this cannot be done, two or three lengths of tile pipe may be laid in the ditch and covered with earth, thus securing a good approach to the building.

292. *Foundation.* A common type of foundation for a battery house, is made by setting posts, about 6 in. in diameter by 3 or 4 ft. long, at each corner of the building, and fastening the

*See **Track Circuits,**—*Installation and Maintenance.*

building to them with strap bolts, secured by lag screws, as shown in Fig. 39.

293. Another simple form of foundation is made by laying two timbers (ordinary railroad ties) parallel to the track, arranged far enough apart so that the battery house just covers them in front and rear. Their surface is generally placed from 2 to 3 in, above ground.

The building should be secured to the ties with $\frac{3}{4}$ in. bolts fitted with O. G. washers, one in each corner being sufficient. After being bolted in place, the house should be plumbed by tamping dirt under the ties.

294. Concrete foundations fitted with anchor bolts may be provided for battery houses if desired.

295. *Maintenance.* An occasional inspection of the general condition of the building is desirable, although the necessary re-painting is the principal consideration.

TRACK INSTRUMENTS

296. When installing track instruments which are secured to the ties, it is customary to use ties of white oak or chestnut. It is very desirable to employ a good quality of wood, as by so doing, not only will frequent renewals of these timbers (requiring re-setting and probably re-adjustment of the instrument) be avoided, but the various parts of the instrument will wear longer and require much less attention.

297. The Hall Track Instrument: *Location.* The principal consideration in locating this instrument is to keep it well clear of rail joints, as, if located near to a joint the creeping of the rail is likely to cause trouble.

If convenient, it is well to place the instrument on straight track, but when necessary to locate it on a curve, it should if possible be placed on the high side* of the track.

*See **Track Work.**

298. Care should be taken to arrange the wires, where they enter the pipe leading up to the instrument from the trunking, in such a manner that they will not be broken by vibration, which is likely to occur at that point. For this purpose the pipe should extend several inches into the trunking, which should fit around it as closely as possible. In addition to this, it is well to bind the wires together with several layers of friction tape, for a length of 12 or 14 in., half of which extends into the pipe.

299. *Position of Lever.* As the operation of this instrument depends upon the blow which it receives from passing wheels, it is important that the end of the lever which comes in contact with the wheels should be located at its proper height in relation to the rail. The upper surface of the lever at this point should usually be about $\frac{1}{8}$ in. above the top of the rail, although where many worn (double flanged) wheels are in service, it may be found desirable to reduce this to $\frac{1}{16}$ inch.

If the lever is set too high, the instrument is liable to be damaged, some part or parts being bent or broken; one of these is the chair, which in this case is likely to be cracked directly beneath the lever. If the lever is too low it will, of course, not receive a blow of sufficient strength to operate the contact. In order to maintain this adjustment a tie plate is provided to keep the rail from cutting into the tie.

The instruments usually come from the factory fitted to a certain height rail, and if used with a new rail of this size, and a new tie or supporting timber, the lever should set properly. However it frequently happens that the rail is worn, being considerably below its original height, also the tie may be worn, the rail having cut into it.

In such cases the necessary steps must be taken to obtain this adjustment which may be done by the use of a thicker tie plate or by slightly dapping the tie beneath the chair.

A clearance of at least $\frac{1}{8}$ in. should be allowed between the end of the lever and the rail.

300. After the instrument has been in use for some time, the end of the lever is likely to become worn by passing

wheels. The fulcrum pin or the hole in the chair may also become worn. Wear at these points may be taken up by placing a piece of sheet iron beneath the chair, making it the same size as the bottom.

Another cause which may make trouble with this adjustment is poor support beneath the tie. The tie must be *well tamped up,* and not allowed to get loose. Therefore ties upon which these instruments are placed will probably require more attention than is given to the ordinary tie.

301. *Tension.* The adjustment of the large rubber spring is accomplished by screwing up or down on the two nuts which hold its yoke. These should be so adjusted that by striking the end of the lever next to the rail a smart blow with a 2-lb. hammer, the piston will rise just enough to operate the contact.

302. *Cylinder.* The sides of the cylinder should be lubricated with a heavy smooth oil, such as red engine oil, or with glycerine, which while allowing the piston to move freely, will keep the air from leaking past it. Whenever the cylinder is open, care should be taken to keep out dust or grit of any kind, as it will tend to roughen the cylinder and piston. Rain and snow should also be excluded as they are liable to freeze and thus cause trouble.

303. *Air Valve.* This is a valve arranged to retard the passage of air from the space above the piston to that below, but allowing it to flow freely in the opposite direction. The adjustment of this valve is to some extent a matter of experiment, a good method of procedure being as follows: Screw the valve down so that the washer will rest on the port, thus offering as much resistance as possible to the passage of air; then note the effect as a train passes. Probably the piston will rise very slowly, and with some wheels, not enough to operate the contact. If this is the case the screw should be raised slightly allowing the piston to rise more quickly. By observing the action of the piston during the passage of three or four trains, an adjustment can be found which will usually be satisfactory,

the piston rising each time sufficiently to operate the contact but not fast enough to prevent it from cushioning properly after it passes the upper port, and is thus kept from striking the top plate or the bonnet.

304. *Contacts.* The contact springs should be so adjusted that they will bend a little after they touch, thus causing a sliding contact.

The contacts should of course be cleaned occasionally, the frequency depending upon the voltage and current carried on the controlled circuit. This may be done by passing a strip of clean emery cloth between the contact points or by rubbing them lightly with a very fine file.* Dirty or greasy emery cloth should never be used.

305. If the contact is normally open and it is desired not to close it while working about the contact, one of the wires may be temporarily disconnected. When again connected, it is advisable to bridge the contacts with a voltmeter, a proper reading on which will insure that the connection at the binding post is well made.

If the controlled circuit is normally closed a temporary jumper may be placed across the binding screws to keep it closed while the contact is being cleaned. To test its operation after the work is completed an ammeter may be bridged in place of the jumper. When thus connected the contact should be opened and then allowed to close, at which time the meter, being shunted by the contact, should give a very low reading.

It is very poor practice, except in cases of necessity such as a failure, to remove the bonnet in stormy weather, as rain, etc., tends to rust the parts and cause them to work poorly.

306. The O'Neil Track Instrument: As stated in Art. 60. the operation of this instrument depends upon the depression or *wave motion* imparted to the rail by the passage of the wheels. With a heavy rail this motion is of course less than with a light one. Also with a firm road-bed, for instance, one ballasted with crushed stone, this motion is less than with a

*Small flat file (Swiss cut).

soft road-bed. Therefore if installing the instrument on a track having a heavy rail and stone ballast it is best to provide a concrete foundation which is entirely independent of the ties, thus utilizing, to its greatest extent, the motion of the rail.

On tracks of lighter rail and softer ballast it may be attached with lag screws to two ties, as sufficient motion may be expected without the use of the concrete foundation.

307. One advantage of attaching the instrument to the ties is that if the track is raised by tamping up the ties the instrument is also raised thus keeping it in its proper relation to the rail. There is a slight disadvantage when attached to the ties however, in that there is more liability of breaking the wires where they enter the box, on account of vibration, than when set on a concrete foundation. The ties to which the box is fastened require a square corner to fit under the lugs, therefore it is advisable to use *sawed* ties.

308. *Maintenance.* Good *drainage* should be provided for these instruments, as water if allowed to run into them, will corrode the parts and may freeze, keeping them from operating.

The contacts should be occasionally inspected, and cleaned when necessary. The precautions mentioned in Art. 305, in regard to keeping the circuit in its normal condition (either open or closed) when working about the contacts, may of course be followed with this instrument.

309. When the instrument is mounted on a concrete foundation, the maintainer should be on the ground when the track is being surfaced or raised, to see that the foundation also is raised to correspond to the elevation of the rail. If attached to the ties and it is desired to adz them beneath the rail, it is also desirable for the maintainer to be present and lower the box if necessary.

TRUNKING, CONDUIT AND WIRING

310. The directions given in *D. C. Track Circuits* for the in-

stallation and maintenance of trunking, conduit and wiring, also apply to other circuits in crossing alarm work.

In order to keep the wires as dry as possible, when running trunking across a ditch, as from the track to the battery house, or across low or marshy ground, as from a filled road-bed to a telegraph pole, where ordinary stakes would not be satisfactory, it is customary to form a bridge of plank. When the span is not over 4 or 5 ft. a 2 in. plank, 4 to 6 in. wide, is laid flat and the trunking nailed to the center. For longer runs it is necessary to set posts (usually railroad ties) between 4 and 6 ft. apart. In some cases, a plank as thick as the width of the trunking is used, being placed on edge. This method produces a rigid construction and is convenient when running to a telegraph pole, as it may easily be attached to it, with spikes, bolts or lag screws.

311. Office wire, secured with cleats, is frequently used in battery houses. It should be kept clear of the battery jars and when sal-ammoniac cells are employed, it should be run above them, when possible, so that in case of a broken battery jar the solution will not drip onto the wires.

When wires are to be carried from trunking into battery houses, the method described in *D. C. Track Circuits,* for use at towers, is usually employed.

312. Battery Wiring: The following directions should be observed in connection with the wiring of bell batteries. When the cells are placed side by side and connected in series, connecting wires between the cells, known as *jumpers*, are frequently required. These are made of the same wire as that leading to the batteries, except in battery boxes, where the heavy under-ground wire is carried directly to the battery terminals, in which case the jumpers are made of lighter material in order to secure greater flexibility. They are usually made from 12 to 15 in. long, being formed into a spiral.

313. The method of installing jumpers for use on batteries connected as shown in sketch B, Fig. 42, varies according to the position of the cells. If the two rows of cells are placed

side by side, the jumpers may be made in the form of the letter H, the sides being about 15 in. long and the piece joining them about 10 in. After completing the joints the cross piece and ends are all wound into spirals before connecting them to the binding posts.

When the two rows of cells are on separate shelves, one above the other, holes, in which the wire will fit snugly, should be made close to the edge of the upper shelf in front of the space between each two cells. The piece joining the sides of the H should be made considerably longer and should be passed through the hole and snubbed, before the second joint is made. In some cases cleats, secured to the edge of the shelf, may be used to advantage to hold these connections. These wires should run straight above and below the shelves, except about 5 in. on each end which is formed into a spiral.

314. As mentioned in Art. 340, it is frequently necessary to arrange batteries so that cells may be removed without opening the circuit. In order to remove the end cells, additional taps or branches are attached to the wires leading to the battery terminals. The joint is usually placed directly back of the spiral, an office wire terminal thus arranged being shown in Fig. 133. The taps are fitted with connectors as shown, when used at the positive end (copper) of a gravity battery.

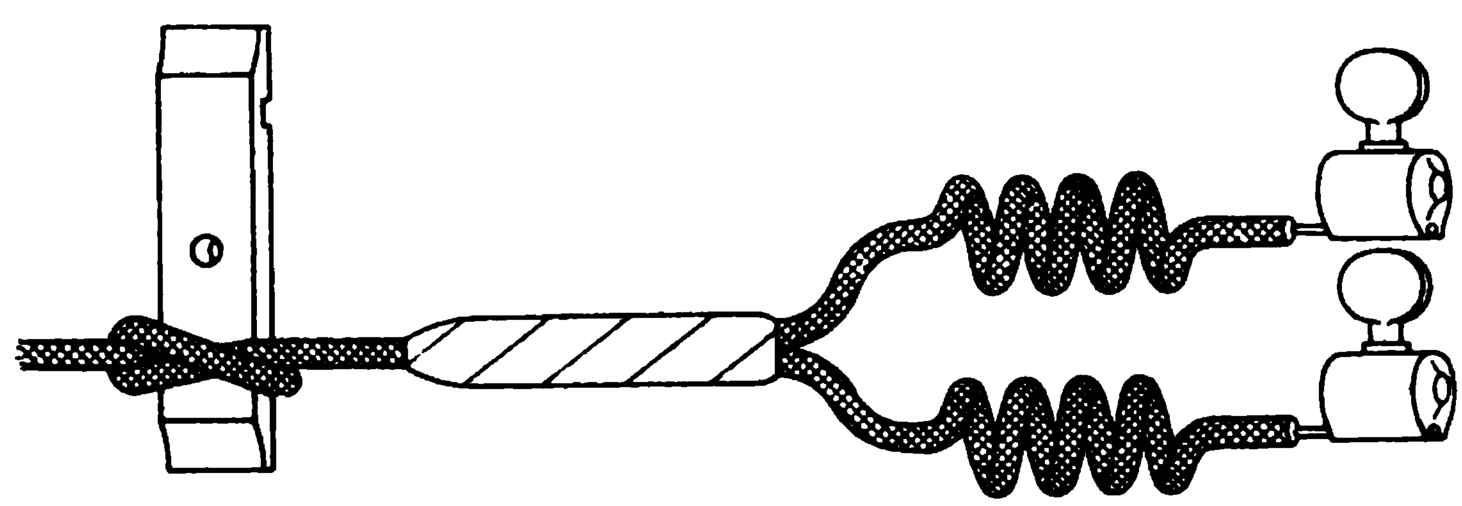


Fig. 133

315. As the chemicals in sal-ammoniac cells attack copper, it is advisable to paint the end of the insulation with P. & B. compound, to prevent corrosion beneath it.

316. The wiring in buildings, such as stations, for interrupt-

ing keys, etc., is usually done as described in *D. C. Track Circuits,* for towers.

When wiring in *insured* buildings, the *Fire Underwriters rules** must be observed. These rules are issued from time to time in book form and when any of this class of work is to be done, it is desirable to secure an up-to-date copy.

The Fire Underwriters have also approved certain electrical fittings for use under these conditions, a list of which may readily be obtained.*

317. Testing: After completing the wiring of a circuit it is desirable to test it for *grounds* and *crosses.* A magneto is usually employed for this purpose.

If the circuit is *isolated,* that is if no part of it is on a common wire with other circuits, this may easily be done by connecting one terminal of the magneto to the circuit at any point and the other, first to a good ground and then successively to the wires of all other circuits with which it is possible for the circuit being tested to be crossed.

If the circuit is *not* isolated the common wire should be disconnected from it at each end and the test then made as just stated.

The common wire should also be tested for grounds, that is of course, unless it is the practice to keep it permanently grounded.

318. Maintenance: Frequent inspection of the wiring about batteries, especially those made up of sal-ammoniac cells, is necessary, the condition of the battery terminal wires and the jumpers between the cells being given particular attention.

The corrosion of a bare wire will be indicated by the presence of a green deposit. However, a wire may become corroded inside the insulation, for instance, if allowed to come into contact with creeping salts; therefore, if a discolored spot appears on the insulation it is well to cut this away to find out if the wire has begun to corrode.

If corrosion has started it is practically impossible to ef-

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*They may be obtained by applying at any Fire Insurance office.

fectually stop it, the only safe course, in such cases, being to renew the wire or if its length permits, cut off the corroded portion.

In some cases a wire may corrode off, or nearly so, before producing a noticeable discoloration on the outside surface of the insulation. It is therefore necessary when inspecting, to try the battery leads and jumpers, by giving them a slight side pressure with the fingers, a little practice enabling one to detect a bad spot in the wire by the resistance it offers to being bent.

319. When it is desired to disconnect a track or line circuit which controls one side of an interlocking relay, it may sometimes be found convenient, especially where traffic is light, to *catch* the relay locked and thus prevent false ringing. For example, if the easterly track battery in Fig. 92, is to be disconnected, it may be done while an east-bound train is between the two track batteries, and consequently when the train leaves circuit B, the relay will remain locked and the bell will not be kept ringing by the absence of the battery.

When doing this, it is of course, desirable to have the battery convenient for use in case a train should approach from the east, as it will be seen that, if allowed to get onto circuit B before the battery is again connected the alarm would fail to give warning of its approach. Therefore, if for any reason the battery will not be available for use within the time that a train could approach from the east. it is advisable to have two or three dry cells at hand to connect to the circuit momentarily and thus unlock the relay. In this case also the dry cells may be used temporarily to keep the bell from ringing until the regular battery is ready to be put into service.

BATTERIES

320. Size of Battery: The number and arrangement of cells to be employed in a line or bell battery depends, of course, upon the voltage required, this being determined by the design of the instrument to be operated. On account of the limiting effect of the internal resistance of the battery upon the flow of cur-

rent, the amount of current required also becomes a factor. For instance, if gravity cells having an internal resistance of 3 ohms each were used, it is evident that (allowing an effective E. M. F. of 1 volt per cell) with the cells arranged *in series*, $\frac{1}{3}$ amp. would be the *maximum* current which could be obtained, no matter how many cells were employed. Therefore, if the instrument required $\frac{1}{2}$ amp. to operate properly, it would be necessary to connect two sets of these cells *in multiple*, in which case the maximum current available would be $\frac{2}{3}$ amp.

321. In addition to the drop in voltage caused by the internal resistance of the battery, another point which must be considered is the drop due to the resistance of the line or other wiring. It should be borne in mind that the voltage given as that required to operate a certain instrument, is the voltage which should be *maintained at its terminals*, when the circuit through its coils is closed. For example, supposing a certain bell, wound to 10 ohms resistance and designed to operate on 6 volts, is connected into a circuit whose wiring has a resistance of 5 ohms, and is to be operated by a battery each cell of which has an effective E. M. F. of 1.3 volts and an internal resistance of 1 ohm. Five cells in series would produce a reading between 6.4 and 6.5 volts at the terminals of the bell when its contact is *open* (as when the hammer is held *against* the gong) but if the contact is *closed* (as when the hammer is held *away* from the gong) the voltage will drop to 3.25 volts. Therefore, to secure the necessary working voltage at the terminals of the bell, the battery must be increased to 13 cells, which will produce a reading of 6.036 volts, when the contact is closed. In this connection, however, it should be remembered that the resistance of the wiring in many of the bell circuits is so small that it need not be considered.

It is customary when calculating the battery required for a circuit, to allow a margin, usually not more than 5 per cent. over the working voltage of the circuit, in order to cover any increase in resistance at contacts, etc.

322. While it is necessary to have a battery large enough to do the work properly, it is possible to have it *too large;* that is, to have too high a voltage on an instrument.

If the voltage is too high, while it may not cause sufficient current to flow to heat the coils, it may cause excessive heating or arcing at the contact points of relays, bells, etc., which will tend to raise their resistance or otherwise injure them. It also tends to increase the effects of residual magnetism.

323. Installing and Maintaining: In addition to the general directions given in *Magnetism and Electricity,* and the special points mentioned in *D. C. Track Circuits* for the installation and maintenance of the various types of batteries used with crossing signals, the following instructions are applicable to their use in this class of work.

As the failure of a circuit on account of unusually high resistance, may cause a dangerous failure of an alarm, it is especially important that all binding posts and connectors be kept *clean* and *bright.*

324. *Gravity Batteries.* When gravity cells are employed in bell batteries or on other light work, there is often not enough flow of current to keep the line of demarcation down to its proper place, therefore when convenient, white solution from the track batteries, which would otherwise be thrown away, may be added instead of water when making up for evaporation. When pouring this into the jars it is desirable, in order that the solution be disturbed as little as possible, to have a thin piece of board (fitted with copper wire for a handle) floating on the top of the solution in the jar.

325. If, as may occur in extreme cold weather, the cells should get cold enough to form ice around the zinc, most of the white solution is apt to be lost in removing the ice and unless additional white solution is available, the battery will be very slow in picking up. In such cases the use of sulphuric acid, as described in *Magnetism and Electricity,* for starting new cells, will be found advantageous.

The necessary visits to the track batteries are usually frequent enough for the inspection of the cells on lighter work. When making such inspections it is advisable to see that the copper connecting wires are not eaten off, this being tested by

giving them a slight pull, although care must be taken not to displace the copper.

326. *Sal-ammoniac Batteries.* When mixing sal-ammoniac solution in glass jars it is well to place them on a dry board so that they will not be cracked by the difference in temperature between the solution, which is quite cold, and the surface beneath.

As the life of a sal-ammoniac battery depends almost entirely upon the number of ampere-hours taken from it, the frequency of renewal will depend largely upon the frequency of train movements, provided the battery is not badly polarized as by allowing the bell to ring continuously for a long time, or by a short-circuit.

Occasionally it will, of course, be necessary to add water to the electrolyte to make up for evaporation.

In most cases it is not desirable to add sal-ammoniac to an old solution, it being much better to substitute an entirely new solution.

327. It will usually be found desirable to keep the condition of all cells in the same battery as nearly uniform as possible, setting them up and renewing, all at the same time. This avoids keeping an individual record of each cell.

If one or two cells in a battery have had to be renewed before the others, on account of broken jars or other damage, and are therefore in good condition when the rest of the battery is exhausted, they may be set one side and kept spare, or used with another battery if desired. This method will, of course, occasionally require the use of more jars and sometimes more material than would otherwise be necessary, but is generally more satisfactory, and, in any case, two or three spare jars at a battery location are always a great convenience.

328. *Binding Posts and Connectors.* As the chemicals in the cells have a tendency to attack the binding posts (as well as the connecting wires mentioned in Art. 318) their condition should be noted at each inspection. When corroded, brass shows a green deposit, and zinc or lead a whitish deposit.

A binding post may, however, become corroded *inside* of the carbon plate to which it is attached and still show very little deposit on the outside. In fact the screw passing through the hole in a carbon may be corroded entirely off and the post remain in place, being held by the paraffin. Therefore when inspecting, a slight pressure should be brought to bear on the binding posts, to insure that none are loose.

Whenever working about the battery care should be exercised not to handle the binding posts, jumpers or wiring, with hands moist with sal-ammoniac solution.

329. *Polarized Cells.* As all types of sal-ammoniac cells are liable to become badly polarized by long continued ringing of the bell or by accidental short-circuiting, it is very good practice for the maintainer to keep at his head-quarters or at some other convenient point, a *dry battery* of the proper voltage, connected up and secured in a convenient manner for transportation, in fact, constituting a portable reserve battery for use when a bell battery at any point has become badly polarized.

By substituting this dry battery in place of the regular battery, the latter can be given absolute rest for a few days, and thus be allowed to depolarize. Of course, the same dry cells should not be kept too long in the substitute battery, it being better to put them into regular service at some point, after they have been in this service for two or three months, and place new cells in the emergency battery.

330. Cells that have been badly polarized will seldom recover their original strength, but if fairly fresh before becoming polarized, a week or ten days rest should be sufficient to restore them to a good percentage of their original efficiency; if at the end of that time the battery is not able to do its work properly, it should be given an overhauling. It is often a good plan to first test each cell separately, as two or three bad cells are likely to reduce considerably the efficiency of seven or eight in good condition.

331. When testing a battery in this manner, it is advisable to test not only each cell separately, but also the cells in con-

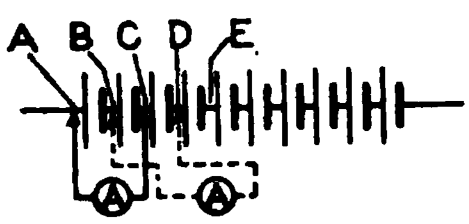

Fig. 134

secutive pairs. For example, in Fig. 134, this would require that the meter be connected from A to C as shown, from B to D as shown dotted, C to E, etc., this test indicating the presence of high resistance at any of the binding posts or other connections.

If only two or three cells are in bad condition, dry cells may be substituted for them during the rest of the life of the battery or their places filled when convenient by cells from other batteries, as mentioned in Art. 327. Whenever substituting, it is well to keep all the old cells together, starting with them at one end, and ending with all the dry cells or substitutes at the other.

332. *LeClanche Cells.* In LeClanche cells, one charge of salammoniac is usually considered sufficient to last as long as one zinc. It is well to clean the zincs once or perhaps twice during their life, and, if convenient, to amalgamate them at the same time, unless they are made of a zinc amalgam.

When the zinc has become reduced to less than one-third its original diameter it should be discarded. The consumption of the zinc to this size indicates that the electrolyte is also exhausted and both should be renewed, the jar being washed out and any crystals that may adhere to the porous cup removed. The cup also should be drained through the tubes at the top, care being exercised not to let any of the solution get onto the binding-post. The new solution and zinc are then put into service.

333. In some cases the zinc may be consumed at the surface of the electrolyte to less than one-third its original size but be fairly large below. In this case the zinc must be discarded and if a partly consumed zinc is at hand it may be used. Before putting in one of these partly used zincs, which has been out of service for some time and has become dry, it should be scraped bright and be thoroughly wet and if not made of zinc amalgam, it should be amalgamated. The cell should be tested when again ready for service.

334. As each successive charge of sal-ammoniac is consumed

in the cell, a certain amount of white crystals form inside the porous cup, starting at the bottom and gradually working up, usually at the rate of about 1 inch for each charge. This crystallization cakes around the carbon and depolarizer forming the whole into a solid mass in which very little action takes place.

Thus after four or five charges of sal-ammoniac have been consumed the crystallization has about reached the top of the solution after which the porous cup will then render very poor service. It may now be boiled out or what is better, given a new charge of depolarizer, and again be put into service. However, on account of the crystallization, the depolarizer is often difficult to remove and the carbon plate or porous cup is liable to be broken in getting it out. The renovated cups also are generally not as efficient as new ones, and the binding posts or the lead caps on the carbons are more likely to corrode. Therefore the results obtained usually do not compensate for the time required to do the work, it being considered better and usually cheaper to throw away the old cups and use new ones.

335. *Other Liquid Types.* Most other types of liquid sal-ammoniac cells employed in this class of work use a depolarizer. If the pencil zinc is employed, the directions given for its use with the LeClanche cells apply to its life as compared with that of the solution; also as regards the depolarizer which seldom lasts longer than four solutions.

In types in which cylinder zincs are used one zinc usually lasts as long as two charges of sal-ammoniac.

336. *Dry Batteries.* In addition to the emergency use of dry cells, as mentioned in Art. 331, they are sometimes used regularly in bell batteries. Their length of life must, in such cases, be determined by experience, and if this is lacking, it is advisable to make frequent tests of the cells, commencing directly after they are installed, to indicate how fast they exhaust.

337. If the paste board becomes discolored or swelled, it indicates that the chemicals within the cell have eaten a hole

through the zinc, in which case the cell should be removed from service.

As the internal resistance of dry cells increases with their age, two or more sets of old cells, each of which is insufficient to operate a circuit, may sometimes be temporarily used, being connected in multiple to decrease the internal resistance.

If some cells become exhausted more quickly than others, it is advisable to add the new cells at one end, as already mentioned.

338. *Caustic Soda or Potash Batteries.* Sal-ammoniac or dry cells are quite satisfactory on alarms where there are not many trains, but where the traffic is heavy, caustic soda or potash cells are more desirable. Even on light work the latter types are preferable when provided with the proper resistance shunt* to keep them in good condition.

Their principal advantage lies in the fact that in case the bell is caused to ring continuously they do not polarize or exhaust quickly. In such cases sal-ammoniac cells soon become polarized, and dry cells exhausted; thus with either type, the bell soon stops ringing, and a dangerous failure results. The battery also requires either an entire renewal or considerable attention, or at least quite a rest, before it is again ready for work.

This, of course, applies to other normally open circuits where sal-ammoniac or dry cells will become polarized or exhausted by a shunt, much more quickly than soda or potash cells.

339. In some cases, if exposed to very low temperatures, soda or potash batteries may lose considerable of their total E. M. F. by the reversal of two or three cells in a battery of ten or twelve. Therefore when testing a battery of this type under such conditions, it is well to note the direction of the current given by each cell, as the removal of the reversed cells may allow the rest of the battery to operate the circuit. The reversed cells should then be short-circuited and warmed, until the current from them again flows in the right direction.

340. *General Maintenance of Batteries.* In order to avoid

*See Magnetism and Electricity,—*Batteries.*

interference with traffic, or false ringing, it is frequently necessary, that, when removing cells from line batteries, the circuit remain closed. This is, of course, also true of bell batteries when arranged to furnish current for line circuits, or when the bell battery is at a distance from the crossing or when the battery at one crossing furnishes current for the alarm at another, in which cases the batteryman might inadvertently keep an alarm from operating for a train, if he should have the circuit disconnected.* In cases where batteries are arranged as in Fig. 42, this is, of course, a very easy matter, especially with the arrangement shown in sketch B, where in a battery of twelve or fourteen cells, the removal of one cell may have hardly any noticeable effect upon the flow of current in the circuit. When employed to control normally closed instruments such, for instance, as relays, one row of the cells shown in sketch A of the same figure, may often be disconnected, if it is first observed that the relay operated by it is *energized*, as it will be remembered that the current required to *hold* up its armature is less than that required to *raise* it.

341. When it is required to keep the circuit closed through a *single* series of cells, the terminal wires are of course provided with taps as shown in Fig. 133, and a jumper is used to shunt out the cell to be removed, before it is disconnected.

The jumpers used for this purpose are made in several forms, frequently of flexible wire, although solid wire is often used. In some cases it is convenient to have a battery connector soldered to one or both ends** while in other cases the bare wire, with the strands soldered if flexible, is preferable. The arrangement and length depend largely upon the type of cells with which the jumper is to be used. For instance, if working about gravity cells employing round zincs, it is usually convenient to have two jumpers, each about 2½ ft. long, one having connectors soldered to each end and the other with a connector on one end only.

To remove the cell at the *negative* end of the battery, one end

*When the bell battery is located directly at the crossing, as for instance, in a box at the foot of the bell post, the batteryman can, of course, guard the crossing while he is working on it.

See **D. C. Track Circuits,—*Wiring in Battery Shelters.*

of the jumper having the two connectors is attached to the additional tap on the terminal wire, and the other to one of the zinc hanger wires of the *second* cell. Thus the *first* cell is *bridged*, by the jumper, and may now be removed without breaking the circuit.

342. If desired to remove the second cell, the same jumper may be connected from a hanger-wire of the zinc in the *first* cell with one in the *third*, as shown by jumper A, Fig. 135. This will of course shunt out *two* cells but if it is desired to have the first cell working while the second is out, jumper B may be connected as shown and jumper A removed or simply disconnected at one end, being replaced when the cell is again to be connected into the battery.

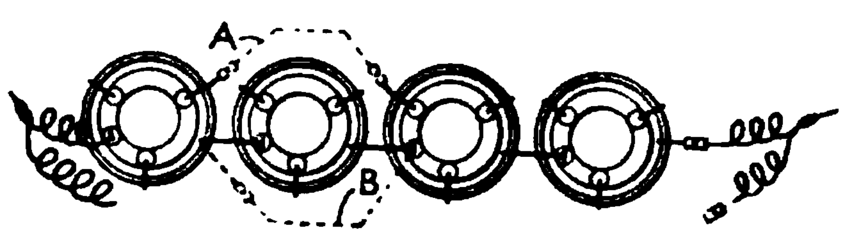

Fig. 135

The same method may, of course, be followed for all other cells in the battery except the last, in which case, the jumper with the two connectors is attached to the connector soldered onto the spare tap, with a short piece of bare wire (just long enough to be fastened into *both* connectors. The other jumper may then be used as before, after the jar is taken out.

343. In Fig. 136 is shown a special connector that is sometimes used when jumping out cells of battery. The jumper is bound into the hole and the lower end may be clamped around a battery connector, at the same time allowing either of the wires ordinarily held by the connector, to be released.

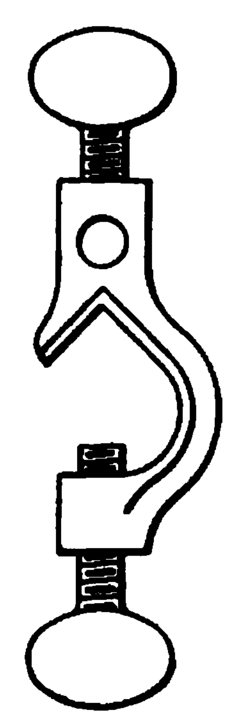
Fig. 136

344. In some instances, the stub of a worn out crowfoot zinc or the binding post and remaining piece of a circular zinc, are attached to a jumper and replaced directly in the electrolyte of the cell thus forming a temporary positive plate; also, a temporary negative plate may be formed with a piece of copper, although the zinc stub is often used for this purpose, being allowed to come in contact with the copper, as it quickly becomes copper coated.

345. The method of "jumping out" cells, as just described for gravity batteries, applies in general to the other type of batteries. It is often convenient to have an additional binding nut to use when securing the jumper to an element as shown in Fig. 137, while other methods will be found to apply to other types of cells.

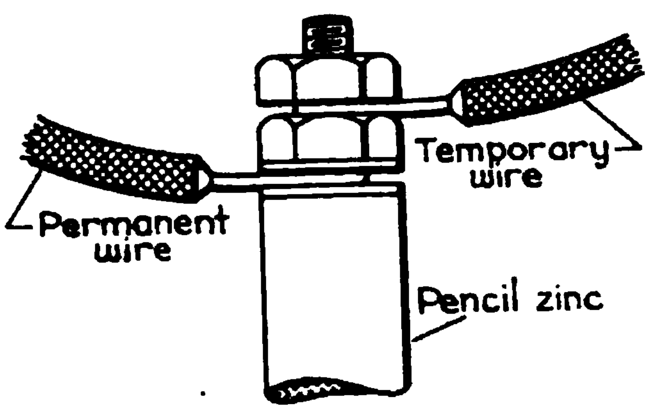

Fig. 137

346. When jumping out caustic soda or potash cells it is desirable, on account of their low internal resistance, to disconnect the cell as soon as possible after the temporary jumper is in place, as when both are connected the cell or cells included by it are on short circuit.

If convenient it is good practice to test the voltage of a battery when the jumper is connected, to insure that it is making good connection.

347. After completing work of any kind on a battery, it should be tested with a voltmeter or other suitable instrument to insure that all connections are in good condition.

348. Special lamps, having large oil fonts, are frequently provided for heating battery houses (Art. 91), although hand or signals lanterns are often all that is necessary.

349. *Records.* It is desirable to keep a record of all work done on line and bell batteries, in a similar manner to that described in *D. C. Track Circuits;* in fact, it is more necessary in this case, as some types of battery employed on crossing alarms require no attention, except inspection, for several months at a time, and unless a record is kept it will often be difficult to remember just what work was last done on them, or in the case of sal-ammoniac batteries, when an entire renewal will be needed.

350. If at any time an open circuit battery should become accidentally short circuited or closed and the bell kept ringing continuously, a record should be made of the occurrence, for example, as follows:

1909	
April 8th.	Battery short circuited 8 hours and run down;* left on open circuit.
April 16th.	Put in service again. 1.3 volts per cell.
May 26th.	1 jar broken, new solution.
June 17th.	Bell rung continuously, 3½ hours; battery kept in service.

351. A similar record is also desirable with caustic soda and potash batteries, as their condition is not easily determined by their appearance.

With gravity batteries on light work, a record of the cleaning of the zincs and of the density of the solution, is all that is required. However, on line circuits, operating low resistance instruments, where these cells sometimes require almost as much attention as those on track circuits, a similar record should be kept.

HIGH VOLTAGE APPARATUS

352. When employing current from high voltage circuits to operate signal apparatus, considerable care must always be exercised to avoid the possibility of dangerous shocks to those whose duty it is to work about the apparatus. It should be remembered that although there may be considerable resistance between the high voltage circuit and the point where a person might come into contact with the apparatus, yet the resistance of the person's body may be so high that the potential to which he would be subjected would produce a severe shock, and while it might not injure him directly, it might cause him to fall from a pole or ladder.

In most cases one side of the high voltage circuit is grounded so that if a person stands on the ground and comes into contact with the signal circuit at only one point he may receive a shock.

353. When installing any of this type of apparatus in insured buildings it must of course be done in accordance with the

*A common term used to signify *badly polarized.*

rules of the Board of Fire Underwriters,* which require special protection for high voltage circuits.

354. Lamps: When lamps are to be used as resistance and it is desired to calculate the number required, it should be remembered that their *hot* resistance differs from their *cold* resistance, that of carbon lamps being *less,* and that of tungsten and tantalum being *greater,* when hot than when cold.**

355. In some cases the lamps are arranged to burn brightly; that is, at their normal voltage for lighting purposes, while in other cases the voltage at their terminals is kept considerably *below* that required to give full brilliancy. The life of the lamps should, of course, be much longer when the latter method is employed. It is advisable, however, when one or more lamps are connected in multiple with the operated circuit, or circuits, to arrange at least one of the lamps in the shunt circuit so that it will glow sufficiently to be observed by the maintainer, in order that he may know that this branch of the circuit is closed and giving the proper protection.

356. If the lamps are to burn at their full brilliancy, their resistance can, of course, easily be calculated from their rating, but if not, it may be found necessary to determine it by measurements.

357. Fuses: The leads from the high voltage circuits are usually first carried through suitable fuses, so that if any part of the apparatus becomes grounded the fuse will be blown before a dangerous overload can result.

358. When working about these fuses, it should be borne in mind that one terminal of the fuse is *directly* connected to the high voltage circuit, and therefore in order to avoid receiving shocks, the maintainer should insulate himself from the ground, for instance, by standing on a dry piece of board.

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*See Art. 316.

See **Magnetism and Electricity,—*Resistance lamps.*

359. In some cases a fuse is also placed in the circuit next to the ground or rail connection. By removing both fuses the whole of the signal apparatus is free from any connection either with the high voltage line or the ground, and will, of course, be safer than when connected with the ground.

360. Cartridge fuses are usually the most desirable type to employ in this class of work, as they are convenient to handle and as there is no danger of them setting fire to adjacent woodwork.

361. Switches: As stated in Art. 81, it is desirable to install switches by means of which the signal circuits may be disconnected from the high voltage circuit. The switch is usually placed in the circuit next to the fuse so that when open all other apparatus will be *dead.*

362. It is usually considered the best practice to employ *snap* switches for this class of work, in order to avoid the possibility of drawing an arc at the contacts when opening the switch.

363. However, on account of the small current usually carried, properly designed knife switches are sometimes satisfactory. When thus employed they should be mounted in such a way that the handle will be *down* when the switch is *open,* thus preventing them from becoming accidentally closed by gravity.

They should be opened with a quick motion so as to avoid an arc. However, if an arc should form and hold after the switch has been fully opened it should at once be broken by passing a piece of dry board or other insulating substance through the arc. If there is no insulating material at hand which may be used for this purpose it is better to close the switch again until something can be obtained. If not immediately extinguished, the arc will melt the metal parts of the switch.

364. It is usually good practice, when working about the switches or their connections, to first remove, or as it is usually

termed *pull* the fuses, thus opening the circuit beyond the switches so that no shock will be received when in contact with them.

365. Shelters: The fuses, switches, and resistances are usually mounted together in a weather-proof box the general construction of which is similar to that used in relay boxes. This box is usually placed about 8 ft. above the ground so that it cannot easily be tampered with.

BELLS AND BELL SHELTERS

366. The selection of the bell and the method of sheltering it, while in many cases governed by standard practice on the various roads, may also, of course, depend considerably upon local conditions, such as the weather, likelihood of interference, etc.*

367. Mounting: The bells are generally fastened to posts, and other supports made of wood, with large wood screws, and to iron posts, etc., with bolts or clamps.

Skeleton frame bells and similar types, and double gong bells are usually hung with the gongs downward.

Owing to the height of the bell above the ground (Art. 43) it is customary to provide a ladder, which may be hinged in the middle. It may be kept in the battery house or other convenient building.

368. Small bells or buzzers are often mounted on the outside of buildings, as in the case of a tell-tale bell or buzzer at a freight house (Art. 191) or a flagman's annunciator over the cabin door. In such instances when skeleton frame bells are employed, a wooden box is usually provided having screens in front and at the sides of the gong.

In some cases, in order that the bell or buzzer may be heard both inside and outside the building, a hole is cut through the wall into the box.

*See Arts. 47-48.

369. Adjustment: The adjustment of the bell is a very important matter, as a good bell may work very poorly or not at all if not properly adjusted.

The proper adjustment of different types of bells varies considerably and in fact different bells of the same type often differ noticeably in this respect so that the adjustment of each bell usually becomes more or less a matter of experiment. However a few rules may be laid down which will serve as a guide in most cases, for adjusting skeleton frame bells and other similar types.

370. The first point to be ascertained is that the circuit is arranged to supply sufficient current to operate the bell. This may be tested with a mil-ammeter placed in series with the bell, or if it is desired to test with a voltmeter, it should, of course, be connected across the terminals of the bell and a reading taken when the circuit breaker is *closed.*

371. *Armature Hanger.* The armature hanger, when adjustable, is usually set so that the armature, when the magnet is energized, will extend parallel to a line drawn between the pole faces of the magnet; that is, if the magnet is provided with stops the armature will rest on both evenly. It is considered good practice in some cases to have the armature strike the lower stop and just clear the upper one. If it strikes the upper one first, the leverage thus produced is likely to greatly weaken the blow on the gong.

As one of the screw heads holding the armature hanger is often placed on the under side of the base,* this adjustment must, in such cases, be made before the bell is put in place.

372. *Armature and Stop.* The armature should not be allowed to approach the pole faces closer than $\frac{1}{64}$ in., and when an adjustable stop is provided it should be set accordingly.

373. *Hammer and Gong.* After the armature has been properly adjusted the hammer should be so arranged that, when the armature is attracted and held against its stop, the hammer will

*See Fig. 2.

just clear the gong, allowing it to vibrate freely if struck having no muffling or deadening effect on the gong.

When the gong is drilled off center this adjustment is obtained by turning it, but in case this method is not available, the desired result may be obtained by carefully bending the hammer rod. When doing this it is usually better to remove the armature and hammer from the bell so as to avoid injuring the other parts.

374. *Tension Spring.* The adjustment of the tension spring should be such that it will draw the armature back its full stroke and bring the contact points together with considerable pressure, which will be indicated by the bending of the contact spring (or springs). At the same time the tension spring must not be adjusted so tight that it will prevent the magnet when energized, from drawing the armature with a strong pull and thus delivering a good blow on the gong.

Another consideration is the wear on the contact points by pressure on them. If this pressure is too great it will cause them to wear out in a short time.

375. *Contact Screw.* As the contact screw serves to limit the backward stroke of the armature and also affects the bending of the contact spring, its adjustment must be considered in conjunction with that of the tension spring.

It will often be found, especially with the large bells used in alarm work, that the armature and hammer act as a pendulum and will operate most satisfactorily if allowed to have a swinging motion which is governed to a large extent by their length.* This motion is of course modified by the action of the springs, but usually a length of stroke can be found by slowly moving the adjustments, which will produce the desired result. After this has been determined, it is usually well to loosen the tension spring slightly or advance the contact screw a fraction of a turn, in order to allow for weakening of the battery which, especially with the sal-ammoniac types and dry cells, is likely to occur after the bell has been ringing continuously for several minutes.

*See **Elements of Mechanics.**

376. Maintenance: *Contact points.* The contact points on the circuit breaker of the bell are usually its weakest point. The arcing which takes place between them tends to blacken them and make poor contact. While the motion between the contact surfaces tends to clean them, it is often inefficient in this respect, and in any case it is very good practice to inspect the contacts occasionally and observe their condition, noting how much they have worn, so that the platinum or other material may be renewed before becoming entirely worn out and causing failure.

377. In many cases especially on smaller bells one contact point is smaller than the other and cuts into it, forming a hollow where dirt will lodge. In such instances, the larger point must be filed off until it presents a smooth surface. Care should be exercised, in doing this, not to remove any more material than is actually necessary, as platinum is very expensive and the life of the contact is lessened with each filing.

378. *Trunnion Bearings.* The condition of the trunnion bearings should be observed when inspecting. Conical trunnions when worn develop lost motion which tends to put the contact points out of alignment. Cylindrical trunnions have been known to cause a failure of the bell by becoming so rusty that they held the hammer in one position. Unless the bearings are employed to carry current it is well to keep them moist with a good quality of machine oil.* Even on bearings which are required to carry current, a small quantity of oil is less objectionable than much rust, as the rust also acts as an insulator.

379. *Springs.* Spiral springs tend to stretch, and flat springs to lose their set (become bent out of their original shape). These changes may in time require the altering of the adjustments.

All springs in time become *fatigued*** by constant bending and will finally break. Their length of life in this respect is determined somewhat by the material from which they are made. Steel is probably the best; then in the order named come german

*"Hydrol" or "Zero Test" Oil, are good for this purpose.

**A change occurs in their physical properties the metal becoming brittle.

silver, phosphor bronze, and brass. Of course steel has a tendency to rust and under such conditions may not last as long as some of the other metals.

The life of a spring is difficult to determine, therefore the maintainer should always be provided with substitutes when inspecting. If in doubt as to the condition of a spring he should stretch or bend it considerably further than is required by the operation of the bell and if it again assumes its normal position, it may be considered good for longer service. If, however, it is nearly fatigued, the extra strain will be likely to break it or leave it so far from its normal length or shape as to indicate that it should be replaced.

380. *Armature Stops.* The rapid succession of blows of the armature on its stop tend either to wear the stop or head it over in case it is a core pin, or to cause it to wear into the armature. The armature may thus be allowed to come too close to the magnet, or the clear tone of the bell be affected.

If the stop is adjustable this is of course, easily remedied but in the case of core pins it may be found necessary to drill them out and put in new ones. However, these pins are usually made of sufficient surface so that they will last for a number of years or until the bell requires a general overhauling.

381. *General Repairs.* After a bell has been in service for a number of years, it will require a general overhauling. The trunnions and their bearings become badly worn; the soft rubber covering on the connecting wires becomes brittle and chips off which may permit grounding onto the frame, thus possibly causing a short circuit or bridging the circuit breaker; the enamel chips off the frame allowing it to rust; the hard rubber or fiber bushings become cracked or warped; and the plated parts become corroded.

382. *Spare Bells.* As it is important that the operation of crossing alarms be interfered with as little as possible, it is very desirable that the maintainer be provided with one or two spare bells (according to the number of alarms which he maintains)

so that in case one is damaged it may be replaced without delay.

383. *Small Bells and Buzzers.* Bells and buzzers located in buildings such as crossing cabins, depots, etc., are sheltered from the weather, although dust working in between the contact points, will sometimes interfere with their operation. Many types are furnished with a cover, either wood or metal, which assists in protecting them.

384. *Failures.* If a bell fails to operate when connected to a circuit of the proper voltage, this circuit should be completed by bridging the controlling contacts, and then testing with an ammeter* connected in series at one of the bell terminals.

No reading or one much *below* the normal current, indicates that there is a *break* or *high resistance* in the circuit.

A reading much *above* the normal current shows that one or more coils of the bell are *shunted.*

A *normal* reading indicates that the bell is out of adjustment or that the armature is hindered from moving freely by some mechanical defect, such as tight trunnion bearings, due to rust. etc. Therefore in such instances it is advisable to inspect the bell with this in view, operating the hammer by hand to insure that it moves freely. However it should be remembered that a shunt in the bell may reduce the voltage at its terminals, by the polarization of the battery, to such an extent that the current flowing through the bell will not be much above normal.

385. If a *break* or *high resistance* is indicated by the test, it may be located by connecting one lead from the voltmeter to one terminal of the bell and touching the other lead at various points along the path of the circuit through the bell. For example, if the bell is wired as shown in Fig. 138, in which binding post A is insulated from the base, while post B is cast as a part of it, one meter lead may be attached to post B. When the other lead is touched on post A, the meter will give a normal reading or higher. This lead should now be touched at con-

*The term *ammeter* here, and hereafter in this part, signifies any instrument giving a reading in amperes or fractions thereof, such as mil-amperes, etc.

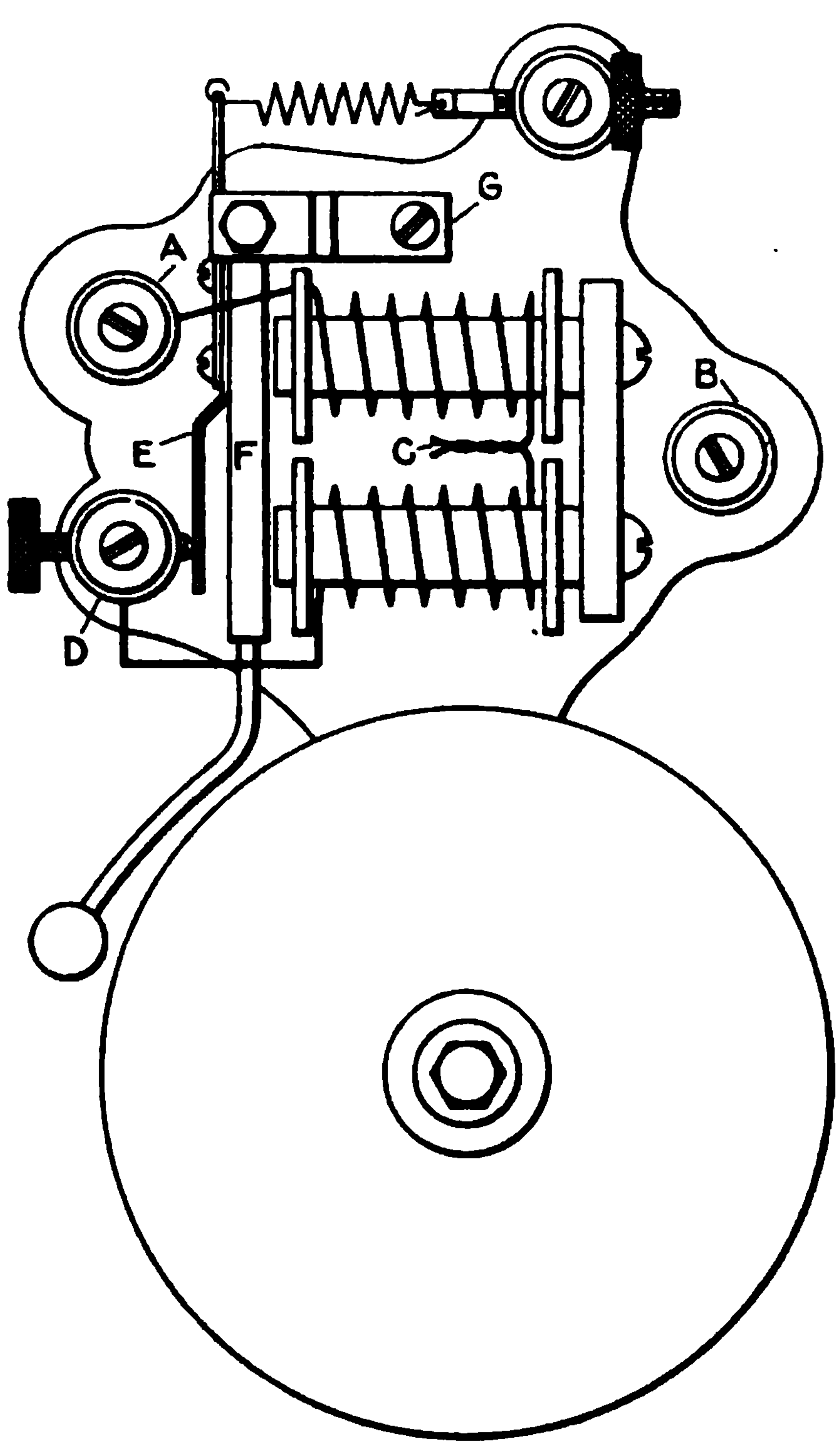

Fig. 138

tact post D and if no reading or a *very* low one is obtained, it indicates that the trouble is in the coils or their connections, which may be located by touching at joint C, and comparing the drop across one coil, with that across the other the trouble being in that portion of the circuit around which the greater drop is obtained.

If a considerable reading was obtained with the meter connected between posts D and B it shows that the trouble is between them. The lead should now be touched on the contact spring, where a very low or no reading indicates resistance in the contact point. If, however, the reading is practically the same the lead should be touched on the armature and then on its hanger, where a considerable difference between any two readings will show that the defective condition has been passed, but if a reading is still obtained when the lead is touched on the hanger there must be resistance between the hanger and the base.

386. If a meter is not at hand, a test can be made by touching with a wire from contact post D to binding post B. If this causes the armature to be attracted it shows that the magnet and its connections are in good condition. In this case, the end of the wire may now be touched at points E, F, and G which will show when the defective connection has been passed, by the magnet failing to attract the armature. If the magnet failed to attract its armature when the wire was first applied, the end should be

taken from post D and touched at joint C; the armature should then be moved up against the magnet and if held there by the latter it shows that the trouble is in the lower coil or its connections, the magnet being energized by current in the upper coil only; if the armature is not retained it, of course, indicates that the defect is in the upper coil or its connections.

387. If the break or resistance is shown by tests to be in one of the coils or its connections, the connections should be examined carefully. The wire lead may be broken or corroded off inside the rubber tubing which is usually employed to enclose it, or there may be poor contact on account of corrosion, where the wire is fastened beneath a washer or binding post.

388. If it appears that the circuit is *dead open*, that is, entirely broken, a magneto is useful in locating the break. The wire should be disconnected from one terminal of the bell and one lead from the magneto attached in its place. By touching the other lead from the magneto to various points in the circuit through the bell, while the handle is being turned, the break can easily be located.

389. If the wire leading from the *outer* turns of a coil is broken off close to the spool a temporary repair can often be made by unwinding one turn and splicing to it. If the end from the *inner* turn of wire is broken off close to the spool it is usually necessary to re-wind the coil in order to make a repair; in such cases therefore if the bell is in service, it is generally advisable to install a substitute bell.

390. If a *shunt* is indicated by the tests described in Art. 384, assuming that the bell is wired as shown in Fig. 138, the hammer should be moved up against the bell, thus opening the circuit breaker, while the ammeter is in series with the bell. If this causes the pointer to go to zero, it indicates that there is connection between some of the turns of wire in the coils, or that there is connection directly from post A to post D, the leads from the coils being crossed. However with bells in which the current is allowed to reach the base, as is done in the types shown,

the shunt is usually caused by the circuit being *grounded* onto the base at post A or in one of the coils, or their leads, and therefore a reading will usually be obtained when the circuit breaker is open. These leads should now be examined if this has not already been done, and if found to be in good condition, the circuit breaker should be opened,* and the terminal of the coil should be disconnected from post A. If when this is done a reading is still obtained, it shows that the insulation of post A from the base is defective. If however no reading is now obtained, it indicates that the defective insulation is in one of the coils.

391. If it is necessary to loosen post A to disconnect the terminal wire of the coil from it, the other wire, or meter lead, which has been connected to this post, should be disconnected, and after the terminal wire of the coil is free from the post, it should be touched to this wire. A reading thus obtained will show that one of the coils is defective, but its absence will indicate that the binding post was defective before it was loosened.

392. In case the tests show the defect to be in the coils, the wire should again be connected to terminal A, and joint C should be opened, which may be done by carefully untwisting it and breaking the solder but taking care not to break the wire. If a reading is still obtained when the joint is open the ground is in the upper coil. if not, it is in the lower.

393. In bells where the circuit is entirely insulated from the base, a ground in each coil, or one ground in a coil and one on a binding or contact post or armature hanger, may shunt out part or practically all of the winding. In such bells if it is thought that there is a ground, the wire should be removed from one of the binding posts and attached to one lead of the ammeter, the other lead from the meter being touched to the base (the edge of the gong is a good point if the base is enameled); a reading thus obtained will, of course, show that the circuit is grounded onto the base.

*A good method to keep this open is to fold up a piece of paper so as to make several thicknesses and place it between the contact surfaces.

394. In order to locate this ground more closely the general method already explained may be employed. For instance, this lead from the meter may be attached to the base (as by binding it under the screw or nut which holds the gong) and the circuit then disconnected at various points as by opening the circuit-breaker, disconnecting terminals of coils from binding or contact posts, etc., and noting the effect upon the meter. The arrangement of wiring the bell will of course modify the method employed, but the principle, that is, of disconnecting portions of the circuit until the reading disappears, is the same.

395. A magneto is also a very satisfactory instrument for locating defective insulation in a bell. When it is used, at least one of the regular wires should be disconnected from the bell, and it is advisable to take off both, so as to avoid the possibility of a false indication during the test.

One terminal of the magneto is then connected to the base, and the other is touched at various points on the circuit through the bell which is disconnected as necessary to locate the ground.

396. In the absence of a meter or other testing instrument, the maintainer can often detect a ground by testing with his *tongue* which is very sensitive to the presence of current. He should first see that he is well insulated from the earth (as by standing on a dry piece of board); then one of the wires should be disconnected from the bell and placed on the tongue, holding it by the insulation, and the base or gong touched with the finger; the current produces a pricking sensation which if now felt shows that there is a ground in the bell. If the current is not very strong it is advisable to wet the finger before touching it to the base. If on the other hand, it is quite strong a sufficient sensation may be obtained on the wet fingers without using the tongue.

If it is found that there is a ground onto the base it may be located by disconnecting at different points in the circuit and again testing as already described.*

*The tongue test will also be found advantageous with other instruments, such as relays, etc., and occasionally on circuits, when no other means of testing are at hand.

397. Cases sometimes occur, in which the hammer is drawn up against the bell and held there as long as the circuit is closed. This of course shows that the circuit breaker is *bridged* as would be done by the grounding of the contact post onto the base in Fig. 138, or the lead from the coil to it. It might also be caused by a ground inside of the lower coil near its terminal, which, as will be seen, would allow most of the turns of wire to be effective in magnetizing the core.

398. Sometimes it will be found, especially in bells which are connected to circuits employing line wires, that the circuit will be both open and grounded in a bell at the same time, this being caused by lightning discharges which, when jumping across insulation, melt off small wires and fuse them together and to the base or cores. A magneto is usually most satisfactory for testing in such instances.

RELAYS AND RELAY SHELTERS

399. In addition to what has been given in *D. C. Relays* and *D. C. Track Circuits* regarding the installation, shelter and care of relays the following points should be considered in highway crossing signal work.

400. Location: Whenever possible, relays controlling the operation of crossing alarms should be so located that the maintainer, when working on them, can hear the bell and can have a convenient view of the crossing and of the highway approaching it on both sides of the track. This is desirable, in order that, when adjusting or testing the relays, he may observe the effect upon the bell and also avoid interfering with traffic on the highway.

401. When relays are placed in battery houses they are either screwed up on the wall at a convenient height, or placed on a shelf. When set on a shelf, a strip about ½ in. high should be nailed along the edge so as to keep the relays from falling off, in case they are moved by the vibration of passing trains.

In battery houses where lamps are used, which may produce soot, or where it becomes very dusty in dry weather, it may be found advantageous to place the relays in a dust proof box screwed up inside the building.

Relays located in stations or similar buildings should be placed in a box or case which may be locked so as to avoid interference.

402. When line circuits are connected to relays which are mounted in boxes on relay posts, it is usually a good plan to place the relay posts on the same side of the track as the pole line, so that it will not be necessary to carry the line circuits across the track.

403. Testing: Before connecting up relays and similar instruments, it is well to test their insulation with a magneto.

404. Adjustment: The adjusting of adjustable relays should be done only under the direction of an experienced man, and after a good adjustment has once been obtained it is usually undesirable to change it, unless there has been some permanent alteration made in the operating circuit, which cannot be satisfactorily taken care of in any other way. The practice, sometimes followed, of altering adjustments as a remedy for a failure is usually very undesirable and sometimes dangerous as the drop-away point, for instance, of a track relay may be lowered so much that the armature, although releasing properly when adjusted, might fail to do so if the resistance in wheel contact were slightly increased.

In some types of interlocking relays also, improper adjustment will have a tendency to keep the relay locked and thus prevent the alarm from operating properly.

It is much better practice, in case a relay, which has been working well on a certain adjustment, becomes weak or operates poorly, to first examine the operating circuit carefully, to insure that this is not the cause of the trouble.

The contacts of relays, which are not enclosed should, of course, be tested regularly and cleaned when necessary.

TIME CIRCUIT CONTROLLERS

405. The installation and maintenance of time circuit controllers is in most respects the same as that of relays.

Clockwork mechanisms and motors used in these devices should be kept properly lubricated with a good quality of machine oil, but care must be exercised in its use not to flood the parts with oil, as when so applied it serves to collect dust and thus clog the machine. After the bearings and other parts requiring lubrication have received a proper amount of oil, all surplus oil should be wiped off. A long nose bicycle oiler is convenient for use in applying oil.

LIGHTNING ARRESTERS AND TERMINAL BOARDS

406. As mentioned in Art. 95, lightning arresters are often omitted from the track circuits. On line circuits, however, their use is usually considered a more important matter, because the line wires which run through the air several feet above the ground are much more subject to lightning disturbances than the rails which are only one or two inches above the ballast.

407. In this connection it should be understood that the protection afforded by ordinary arresters against lightning discharges cannot be considered complete; that is, they are not designed to take care of a *direct stroke** of lightning.

While it would be possible to make arresters that would be able to do such work, such arresters would be much more expensive than the apparatus which it is required to protect. Moreover such discharges are exceptional, especially on the ordinary length of lines used in signal work. When they do occur, the ordinary arresters, the instruments, and occasionally considerable of the wiring are usually destroyed.

408. However it is considered possible to avoid much of the damage which may be done by *secondary* or *induced discharges,** which frequently occur, the types of arresters described in

*See **Magnetism and Electricity**.

D. C. Track Circuits being employed to take care of such discharges. In the diagrams there shown, it will be observed that arresters are connected to the circuits controlled by the track relays as well as to the track circuits. These controlled circuits, while they are sometimes other track circuits, as for instance in the case of a relayed track circuit, are more often line circuits, the wires from the line in such cases being connected to the arresters in place of those marked "from track".

409. In some instances the arcing at the spark gap draws metal across the gap and permanently grounds the circuit. In order to avoid trouble from this source, it is sometimes the practice to connect the arresters so that the fuse will come between the line and the spark gap. When so arranged if sufficient current comes in to draw up the metal at the spark gap, the fuse will probably be blown and the circuit thus opened.

In other cases, especially where the apparatus is not easily reached and the discharges are light, this arrangement would be considered a disadvantage, as the fuses might frequently be blown by a discharge which would not do any other damage, and thus the circuits would be open and consequently out of service until the maintainer could get there and replace the fuses, which in many instances would require several hours. In such cases the fuses, when used, are placed next to the instrument so that if the spark gap and choke coil fail to relieve the discharge, the fuse will be blown before too much current reaches the instrument.

410. In some instances the arrester shown in *D. C. Track Circuits*, which is equipped with three ground plates, is arranged with the two ground plates, 2 and 3, connected one to each of the wires leading to the track. The reason for this is that the rails form a partial ground, especially after it has been raining, and thus there will be a tendency for the lightning discharge to jump to the rail connections and be relieved in that manner. With the spark gaps thus arranged this arcing can take place at this point and so be kept away from the relay.

411. When connecting up lightning arresters which are not

arranged for the circuit to pass *through* them such, for example, as a simple spark gap arrester, the wiring should be so arranged that the arrester cannot become disconnected without opening the circuit.

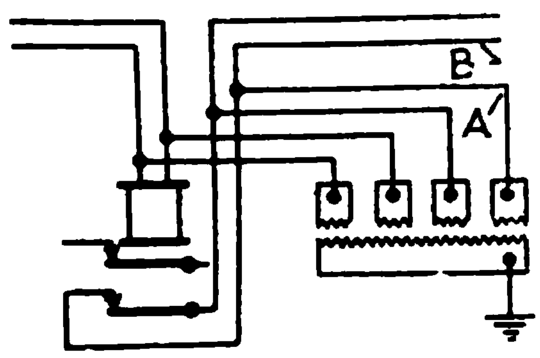

Fig. 139

For instance, if the arrester should be connected as shown in Fig. 139, the breaking or disconnecting of one of the taps as, for instance A, would render the arrester useless for relieving a lightning charge from line wire B, and such a break might remain unnoticed for some time.

412. On the other hand if the arrester were connected as shown in Fig. 140, the probabilities are that if any of the saw tooth plates should be disconnected one of the circuits would be opened and thus the defective condition would at once be noticed and remedied. It is, of course, the best plan except, possibly, in the case of the common wire, to use an arrester with two binding posts for each wire so that the circuit will have to pass *through* a portion of it to be complete.

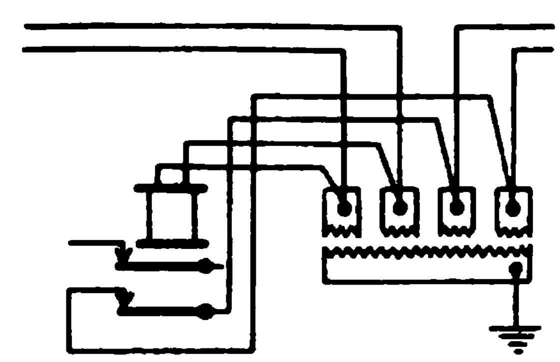
Fig. 140

413. *Grounds.** In order to carry off discharges satisfactorily, the path from the line to ground must be as free as possible from inductance and resistance except of course the *spark gap* which should be as short as possible. If, when using ground rods or pipes** driven into the ground, one is found not to have sufficient conductivity, two or more connected in multiple may be used, but they should not be driven close together, as it has been found that two rods or pipes placed close together have about as much resistance as one. If a space of 6 ft. or more is allowed between them, they get separate "current fields" and both become effective in reducing the combined resistance to ground.

414. If the ground is quite dry and therefore unfavorable

*See **D. C. Track Circuits.**
**A piece of 1 in. galvanized iron pipe of suitable length is satisfactory.

for grounding, several handfuls of salt* placed at the top of the rod or pipe, and wet occasionally with a pail or two of water will tend to reduce the resistance of the ground. The brine thus formed soaks into the ground to a considerable depth and retains much of the moisture that collects about the rod.

415. When installing arresters in which fuses are employed, care should be taken to see that no fuses are connected so that a dangerous condition could be caused by the fuse being blown, as mentioned in Arts. 101, 136, etc. If the location of the arrester is such that the blowing of the fuse would cause such a condition, the fuse should be omitted, a piece of copper wire of the same size as that used in the wiring, being connected across the space ordinarily occupied by the fuse.

416. Location: The location of arresters and terminal boards or terminals, when placed in relay boxes, is of course, the same as described in *D. C. Track Circuits.*

Their location when used in battery houses will be determined largely by that of the relays, or other instruments, and by the manner in which the wires are brought into the building. The type of instrument, that is whether it is of the wall type or not, also tends to govern the arrangement. If the wires are brought in near the ground, as from trunking, and the instruments are of the wall type, it will usually be found most convenient to mount the arresters or terminal board below the instruments. On the other hand if the wires are brought down from the line and enter the building near the top it will probably be better to mount them above the instruments, especially if the latter are of the type which are placed on a shelf. In some instances wires are brought in both above and below the instruments, and as it is usually desirable to have the arresters or terminals all in one group, their location will have to be determined by the type of instruments used, convenience for inspection, etc., also being one of the important considerations.

417. Maintenance: Frequent inspection of lightning arresters is necessary, and especially so with those connected to

*A cheap quality of rock salt is quite satisfactory.

line circuits, on account of the possibility of circuits becoming permanently grounded through them.

418. A case in which grounds in arresters may cause an instrument to be falsely energized is shown in Fig. 141. If the spark gap should become bridged, as shown at X and Y, a path,

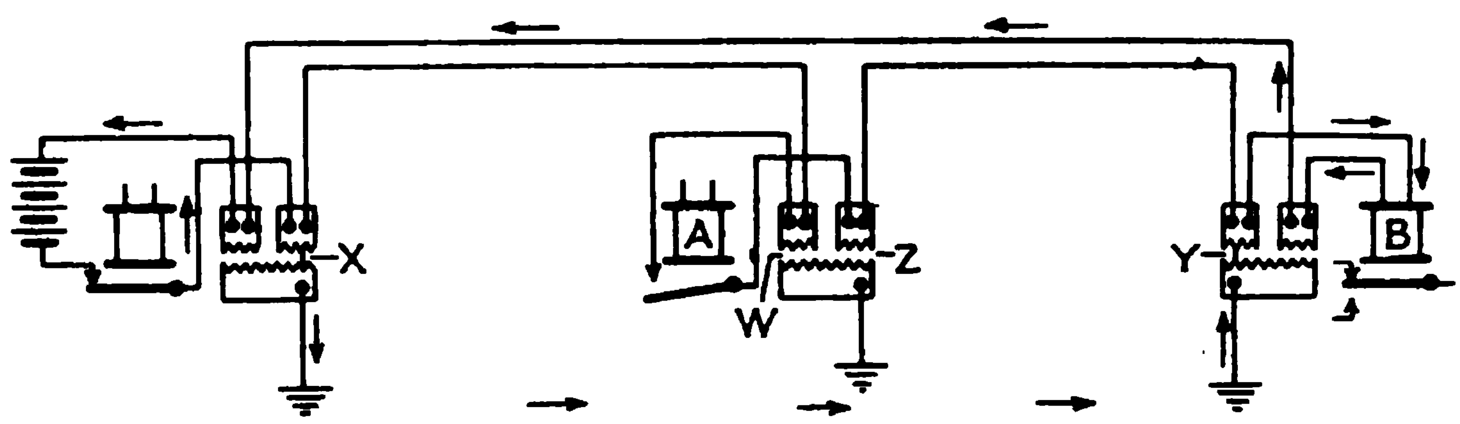

Fig. 141

indicated by arrows, would be formed around the contact of relay A (which is open) and thus relay B would be falsely energized. The same effect would of course be produced if the gap at W were bridged instead of at X, or at Z instead of at Y.

419. Another example of the trouble, which may be caused by grounds is illustrated in Fig. 142, in which relay A is normally controlled by relay B and should therefore be de-ener-

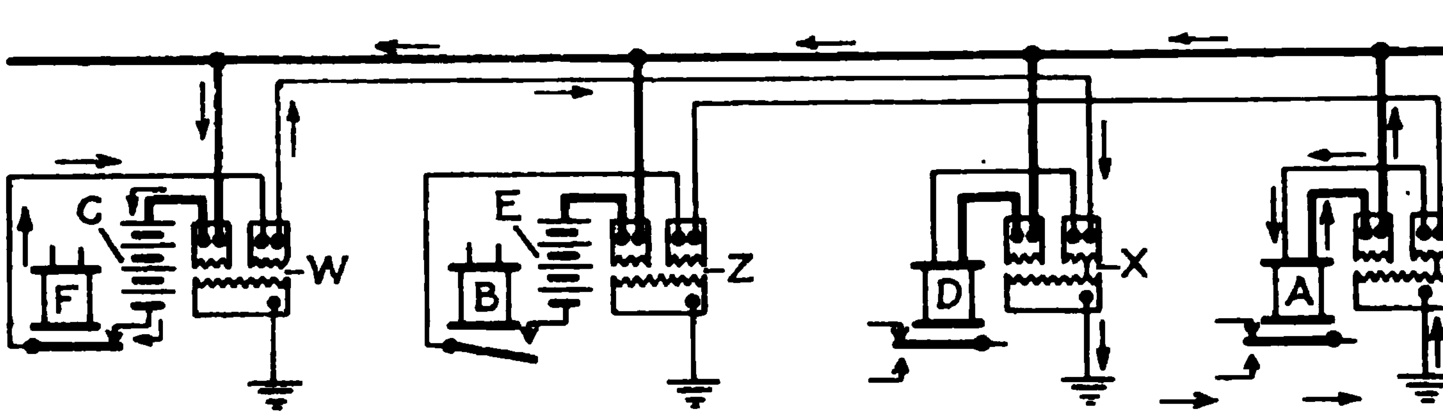

Fig. 142

gized, as the latter is open. However, on account of connections across the spark gaps at X and Y in the arresters, relay A is falsely energized by current from battery C through the path indicated by arrows. Relay D would also be falsely energized by current from battery E if relay B should be closed when relay F is open, current passing through the ground in the opposite direction. A similar effect would, of course, be produced if the spark gap at W were bridged instead of at X, or at Z instead of at Y. In other words, *grounds on two wires amount to a* **cross**

between these wires, and if they are each control wires whose circuits use the same common return wire, or if one is a battery wire, the instrument operated by either circuit is likely to be falsely energized. It will also be noted that the two grounds causing the trouble may be several miles apart, that is anywhere within the limits of the same common wire. For this, as well as other reasons, it is customary on some roads to *limit* to a few miles, the length of common return wires (Art. 592).

420. As a ground may remain effective for a long time unless discovered when inspecting, such inspections should be very thorough, it being desirable to occasionally test all wire *for grounds.* This may be done by connecting one terminal of a magneto to the ground wire and while the handle is being turned, to touch the lead from the other terminal to each wire connected to the arrester successively, a ring obtained on any wire indicating that it is grounded. When conducting this test the lead which is touched to the various wires should, of course, first be touched to the ground plate to insure, by getting a ring, that all connections are good.

421. If a ring is obtained on any wire it should be completely disconnected from the arrester and the test repeated first on the arrester terminals and then on the wire. A ring obtained on the arrester will of course show that it is defective. If a ring is obtained on the wire, it will indicate that it is grounded at some other point or points. Other arresters on the circuit should then be tested in a similar manner until the ground or grounds are located and removed and the circuit gives no *ring to ground.*

422. Another test which is often convenient especially on normally closed circuits, is to ground one terminal of a voltmeter and touch the lead from the other terminal to each wire successively. If a reading is obtained when this lead is touched to the common wire it will indicate that some control wire, whose circuit is connected to this common, is grounded. If a reading is obtained from a control or battery wire it indicates that the common wire is grounded.

423. On installations where it is the practice to have the common wire permanently grounded the magneto and voltmeter tests just described cannot, of course, be employed. In such cases each arrester or group of arresters should be tested by disconnecting the ground wire and testing with amagneto between the ground plate of the arrester and each wire connected to it. After the test is completed and the ground wire again connected it is well to insure that the ground connection is good by getting a ring on the magneto between the ground plate of the arrester and a separate ground such as may be obtained by touching on an iron bell post or in a pool of water.

424. Care should be taken not to handle arresters or terminals with hands which are moist with battery solution, on account of its corrosive effect. However, if an arrester or terminal should become badly corroded from this or any other cause, it should be replaced.

ANNUNCIATORS

425. The installation and maintenance of annunciator bells is described in Arts. 368 and 383. When installing such bells the batteries and relays employed with them are generally placed upon a shelf, or in a cupboard, built for this purpose, in the flagman's cabin.

426. An arrangement of circuits which may sometimes be used to advantage where it is necessary to install an annunciator

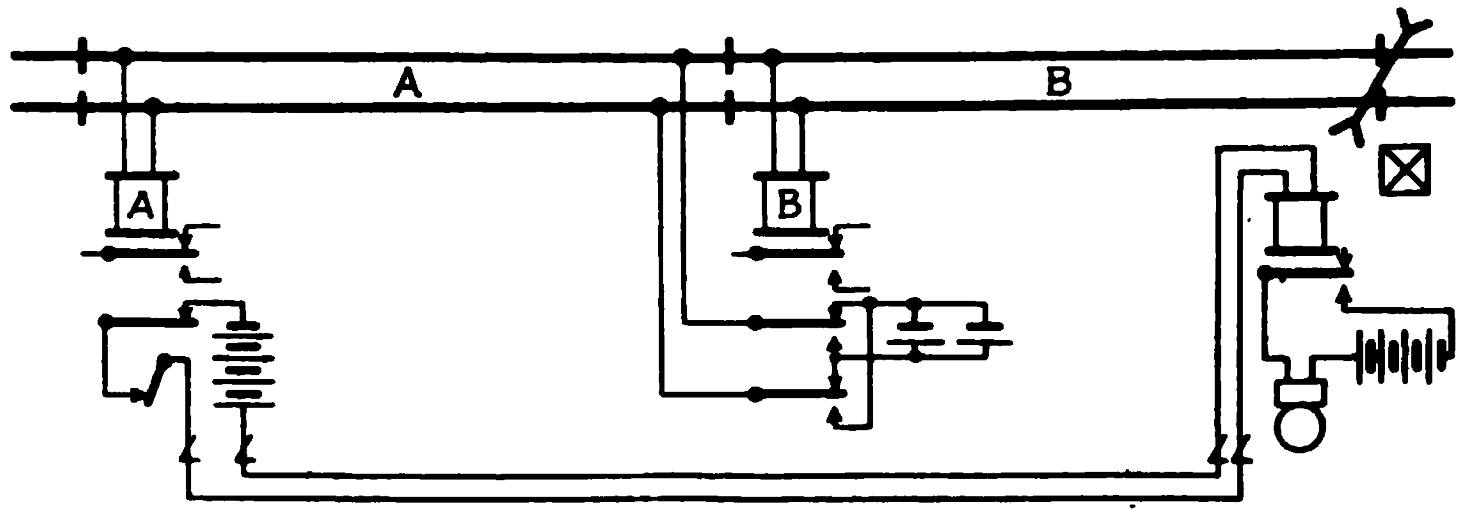

Fig. 143

as quickly as possible, or where there is a likelihood of changes being made in the track circuits, is illustrated in Fig. 143. In

this arrangement the polarity of circuit A is controlled by neutral contacts on relay B. The line circuit of the annunciator is controlled through both neutral and polarized contacts on relay A. Thus the presence of a train on either track circuit will hold the line circuit open and consequently ring the bell. However. the additional apparatus controlled by the upper neutral contacts on relay A, and that controlled by the upper contact on relay B will each operate for trains on their own circuit, being entirely independent of each other. The additional apparatus controlled by relay A must, of course, be provided with the proper slow releasing feature, to retain it in position during the change of polarity.

Thus it is evident that the cutting of the line circuit at relay B is avoided and therefore the circuit may be installed quickly. Also, if it is desired to take out the cut section at relay B, it may be removed without requiring a change in the annunciator circuit wiring.

CUT-OUT SWITCHES, TEST KEYS, ETC.

427. Location: Cut-out switches, and keys or switches for use when testing the condition of alarms, while sheltered from the weather, must of course, be accessible to those whose duty it is to operate them.

When the relays employed are mounted in a relay box, these keys or switches are often placed in a separate compartment in the lower part of the box, the door of which is secured with a separate lock, generally a switch-lock.* Thus the alarms may be tested, or cut out, if ringing continuously, by the track patrolman or other person, who has no occasion to get at the relays or other apparatus.

428. Where a battery house is used a small box, similar to a relay box, is attached to the outside of the building at a convenient height (usually from 4 to 5 ft.) holes being bored through the back of the box into the building for the wires.

*That is, the pad-lock used on hand switches; as most employes are provided with keys.

It is advisable to have the door hinged at the top, so that if carelessly left unfastened it will remain closed.

429. Mounting: Cut-out switches when of the knife switch pattern should be mounted so that the handles will be *down* when *closed,* but when open will swing back far enough to remain open if placed in that position. When thus arranged there will be no danger of them opening by gravity.

430. When used as test keys knife switches, if arranged *normally open* and connected so as to *shunt* the current out of the track relays, should be mounted so that the handles will be *down* when the switch is *open* and thus cannot be closed by gravity. If arranged *normally closed* and connected *in series* with the track circuits, the handles should of course be *down* when *closed,* and so arranged that it cannot swing back and remain open.

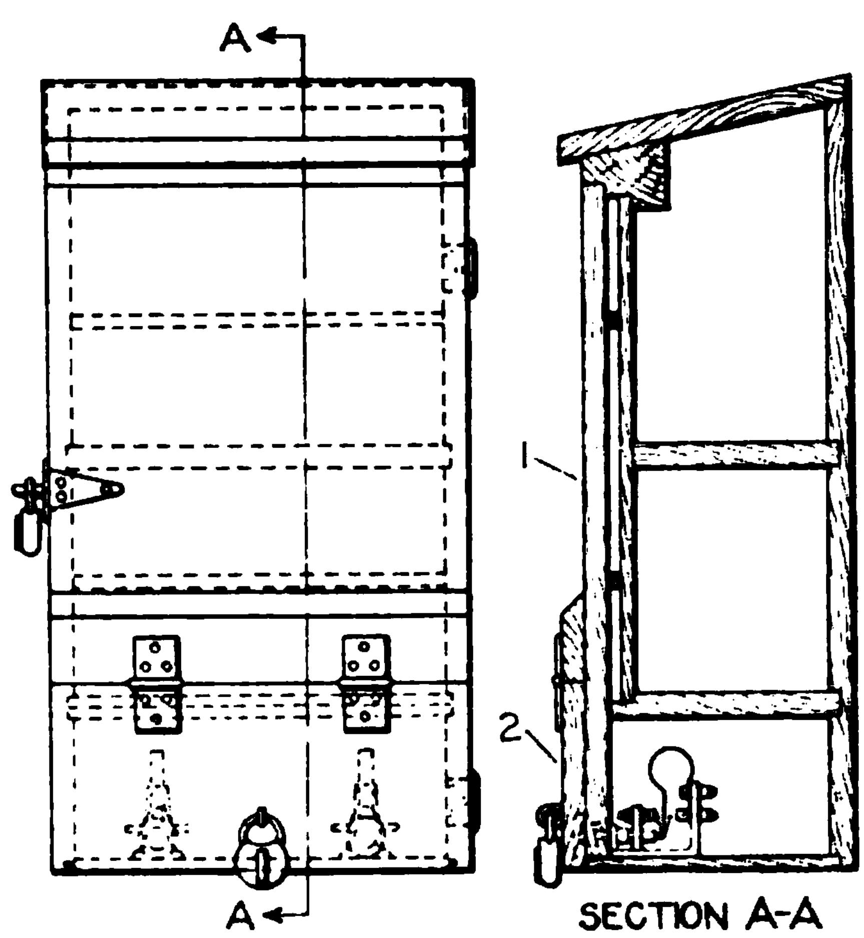

Fig. 144

431. One method of mounting a test key, is shown in Fig. 144. It will be observed that two doors, 1 and 2, are employed, and that door 1 extends entirely over the three compartments, door 2 being attached to it. It will also be observed that when door 2 is opened, door 1 still closes the lower compartment, but the operating portion of the testing keys extends through it, thus allowing them to be operated.

432. Marking:. Cut-out switches and test keys should be plainly marked, as for instance, "Cut-out switch", and if on double track, the direction should be given, as for example, "East-bound" or "West-bound". Test keys on single track are usually marked according to the location of the circuit to which

they are connected. For instance, "Test key Eest" means that this key is used for testing the easterly track circuit.

433. It is advisable to have all designations printed on slips of a good quality of paper and pasted up close to the switch or key.

434. Maintenance: The contact surfaces of switches and the contact points of keys and push buttons should be inspected and cleaned whenever necessary to insure good contact. Fine emery cloth is usually satisfactory for this work, although a fine file may be found desirable for use on the platinum contacts of keys. Emery cloth filled with brass or copper should not be used on platinum contacts.

INTERRUPTING KEYS

435. Location: When located at the crossing, interrupting keys may be sheltered in the same manner as just described for cut-out switches and test keys, but should be placed in a separate box or compartment from the latter apparatus, so that the trainmen will not be confused; in fact, where both are located at the same crossing it is well to employ two different style locks, using the switch lock for the box containing the interrupting keys, as trainmen generally carry switch keys.

A similar box to that used on battery houses may be employed at freight houses or on the outside of passenger stations.

In ticket offices, etc., the keys may be mounted directly on the desk or wall, the latter location usually being somewhat more desirable, as they are less likely to be operated accidentally, as for instance, when putting down books or moving them about on the desk.

436. Marking: In order to avoid mistakes in operation, interrupting keys should be marked to indicate their function, as for instance "West-bound stopper", "East-bound starter".

437. Maintenance: The keys should be tested at suitable intervals, by the maintainer, especially starting keys, as their

failure to operate properly might produce a dangerous condition.

The contacts should, of course, be inspected and cleaned when necessary. If, as is the case in some arrangements, it is not desirable that the keys be operated while the contacts are being cleaned they may be temporarily disconnected or bridged, as described in Art. 305.

GATE SIGNALS

438. Gate signals are operated as either *absolute* or *permissive* signals and are located from 100 to 1,000 ft. from the crossing.

Absolute signals are usually located close to the crossing, so that in case a signal fails, the train may approach close enough for the engineman to observe that the gates are closed or to receive a hand signal from the flagman, and thus reduce to a minimum, the consequent delay.

The arrangement of gates and signals operated from an interlocking machine, as mentioned in Art. 216, is employed where there is an interlocking plant, with the tower so located that a good view is obtained of the crossing and its approaches.

In such instances the gates are usually interlocked with the most convenient main line signals. In some cases it may be found advantageous to change the location of a signal a short distance from where it otherwise would be, in order to protect the crossing properly.

The signals shown in Fig. 91 are, of course, installed and maintained as described in *D. C. Power Operated Signals.*

When gates are operated by a mechanical interlocking machine, they are frequently pipe connected, although some types are arranged to be operated by wire connections. The length of stroke required, the manner of connecting to the gates, etc., vary considerably in different designs and will usually have to be taken care of on the ground, being arranged to suit the special conditions arising at each location.

FAILURES OF BELL CIRCUITS

439. If a bell, whose circuit is controlled through only one contact,* fails to ring, it is well to test this contact by bridging it with a piece of wire. If the bell rings when its circuit is closed through the wire, and not when the contact is closed, it of course, shows that the contact is defective. If the bell circuit is controlled through two or more contacts connected in multiple,** and fails to ring when one of them is closed, it is well to try the others before making any further tests, as the fault may thus be located in one contact or in the branch of the circuit leading through it. If, however, the bell fails to ring through any of the contacts controlling it, the next step is to test the source of energy, which is in most cases, of course, the bell battery, making sure that it is able to maintain a proper working voltage on the circuit when the controlling contact is closed. If when thus tested, the battery maintains its voltage properly, it indicates that the trouble is elsewhere in the circuit.

If an ammeter is convenient, the next step is to connect it in series with the battery and again close the circuit at one of the controlling contacts. If *no reading* is obtained it may now be assumed that the circuit is *broken* at some point. If a *low* reading, that is, lower than the normal current used by the bell, is obtained, it indicates that there is *high resistance* in the circuit. The method of procedure is the same in either case.

440. Broken Wire or High Resistance: If from tests made it is determined that there is a break or high resistance in the circuit, it is well to attach a jumper so that it will bridge one of the contacts which completes the bell circuit, and then inspect the bell. A voltage test should first be made at the terminals of the bell. If a normal reading is obtained, it is evident that the bell is out of order, and must be tested as described in Art. 384. If no voltage, or a low reading, is obtained, it is apparent that the circuit is broken or that there is high resistance at some point outside of the bell.

*This is understood to mean either a *single* contact, or *two* or *more* connected in *multiple*, operated by one armature (see footnote Art. 93).
**That is, contacts on different armatures.

441. If a sufficient length of wire is at hand, one end of it should be connected to one terminal of the battery and the other end touched first to one terminal of the bell and then to the other. If no results are obtained with it connected to one terminal of the battery, it should be attached to the other, and the test at the bell repeated. Unless there is more than one cause of failure present, the circuit should now be completed. It is well to keep the voltmeter connected in multiple with the bell when making these tests. A good reading should be obtained when the test wire is touched to one terminal and no reading when touched to the other; however, in the latter case there may b a spark or flash when the test wire is removed indicating that considerable current is flowing when the battery is short-circuited. For example, in Fig. 145, if the wire is broken at point X, and a jumper is bridged around one of the relay contacts as shown at A, the bell should ring and the meter show a normal reading when the test wire B is touched to terminal C, and when touched to terminal D it may produce a spark especially if a battery of low internal resistance is employed, because, as will be seen the battery is practically short-circuited when the test wire B is in contact with terminal D.

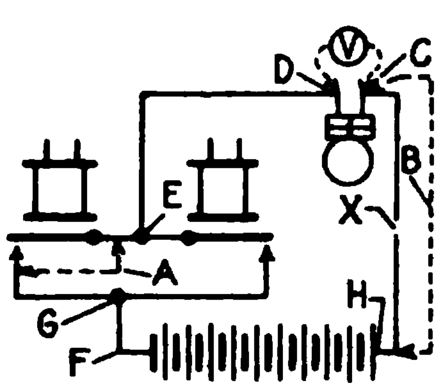

Fig. 145

If the break instead of being at X were in the other lead to the bell, that is, between terminal D and point F, the test wire as applied would have no effect, but if attached to the *other end* of the battery, that is, at F, a similar result would be produced, the bell ringing when touched to D and a spark produced at C.

442. Another method sometimes used under similar circumstances is shown in Fig. 146. As will be seen the voltmeter is cut into the test wire B.

The circuit through the bell should now be broken, by holding the hammer against the bell.* With a break at X, a full voltage reading will be obtained by touching on terminal D, and no reading by touching on terminal C. If there

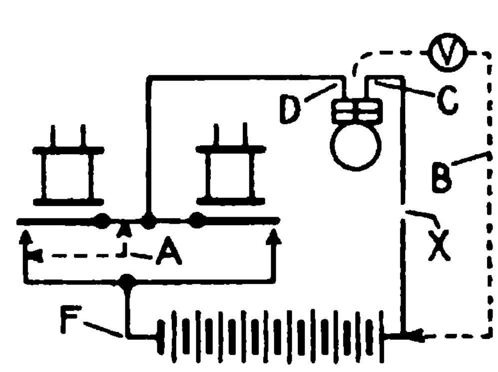

Fig. 146

*That is, with the ordinary type of bell; of course, with some types, as for instance that described in Arts. 37-41, this does not apply.

were a break between D and F, instead of at X, there would be no reading obtained from either terminal, but with the test wire connected at point F, a reading would be obtained by touching terminal C.

443. If instead of the circuit being broken as shown in Figs. 145-146, there is unusually high resistance at the points mentioned, there may be *low* readings on the meter during the tests, but usually these can easily be distinguished from the *normal* readings obtained when the circuit is properly completed.

444. If it is found that the defect is between points D and F, Fig. 145, it must then be determined whether it is between the battery and relays (that is, points F and G) or between the relays and the bell (points E and D). To accomplish this a test jumper is placed in parallel, first with one of these wires, and then with the other, jumper A still being left in place. The bell will, of course, ring when the defective portion is spanned by the test wire.

445. When it is found what portion of the circuit is defective, a temporary wire may be put into service while the permanent wiring is being examined. For instance, if the defect is found to be at X, the temporary wire may be left connected in multiple with the length of wire from C to H, until this length is repaired or replaced.

446. Shunts: If, when the ammeter is connected in series with the battery as mentioned in Art. 439, a ***high*** reading, that is, equal to or above the normal current of the circuit, is obtained and the bell remains silent, it indicates that the current is being shunted out of the bell through a cross caused by defective insulation, etc. In some cases an ammeter cut in at one of the battery terminals may give a reading when all relay contacts are open; in other cases the reading will be obtained only while a relay contact is closed or bridged. For instance, in Fig.

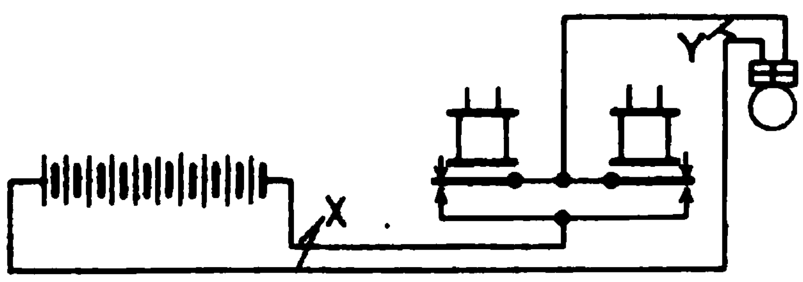

Fig. 147

147, if the cross or defective insulation is at point X, it will produce a reading on the ammeter whether the relay contacts are opened or closed. If, instead, the shunt is at point Y the meter will give no reading unless the circuit is closed at one of the relay contacts.

447. Of course, instead of being in the wiring at point Y the shunt may be due to defective insulation in the bell and produce the same result. Therefore if this condition is indicated it is advisable to cut the ammeter in series at one of the bell terminals and note what reading is obtained when one of the relay contacts is closed or bridged, a high reading of course indicating that the shunt is in the bell, and a low reading, that it is in the wiring. If located in the bell it should be further tested as described in Art. 384.

448. Another method which may be employed in testing for defective insulation, is to disconnect both sides of the circuit and then test with a magneto, one terminal being connected to one side of the circuit, and the other terminal to the other side, or to the ground. This method may, of course, be employed in connection with any of the tests, hereafter described, for locating defective insulation, causing shunts or grounds.

449. If a shunt is located in the wiring that portion of the circuit in which it occurs will, of course, have to be examined, and while this is being done it is well to employ a temporary wire to keep the alarm in operation. This may be arranged as shown in Fig. 148, wire A being used if the trouble is at X, and B, if at Y. The permanent wire must, of course, be disconnected at *both* ends to remove the shunt.

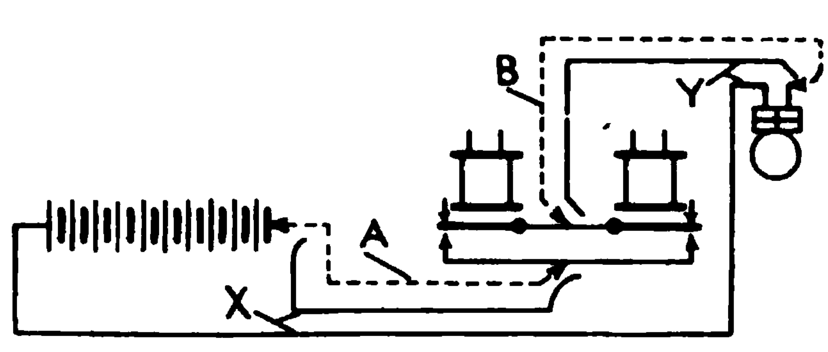

Fig. 148

450. In cases where it is the practice to have one side of the circuit permanently grounded, a shunt may of course, be caused by the grounding of the other side, thus defective insulation on only *one* wire may be the cause of the trouble. However, where it is the practice to keep the circuit entirely insulated from the ground, it will require defective insulation on both sides of the circuit, that is on *two* wires, to produce a shunt.

FAILURE OF LINE CIRCUITS

451. Normally Closed: If a normally closed line circuit fails to energize its relay properly, it is well to take a voltage reading at the terminals of the relay. If the relay does not pick up with the proper working voltage at its terminals, it is of course out of order.

If the voltage reading thus obtained is low, an ammeter should be connected in series with the relay, a current reading above the pick-up point also indicating that the relay is out of order. If this current reading is below the pick-up point, the resistance of the relay should be roughly estimated by Ohm's Law, to insure that there is no shunt in the coils.

If the relay is defective, it must of course be taken out of service and a substitute relay put in its place, unless the trouble can at once be located by inspection and remedied.

452. Assuming that the battery is at the further end of the line,* then if the relay appears to be in good condition (the voltage reading at its terminals being below normal) the meter should be bridged across the circuit outside of the lightning arresters, and if a normal reading is obtained there, it will indicate a high resistance between that point and the relay, which may be located by connecting a test jumper in multiple with the arresters and leads to the relay, first on one side and then on the other. The relay will, of course, pick up when the test jumper is in multiple with the defective arrester or lead.

453. If a low voltage reading is obtained outside of the arresters one of the incoming wires should be disconnected and a voltage reading then taken, which if normal or slightly above,

*Methods of procedure for batteries in other locations are described later.

will indicate that there is defective insulation in the arresters or between them and the relay. To confirm this indication, a test jumper may be connected from this wire which has been detached from the arrester and carried clear of the arrester to the relay terminal, the lead to the latter being temporarily disconnected, as shown in Fig. 149, in which the test jumper is shown dotted. The relay should in this case be energized when the test jumper is thus connected. The arresters and their leads should then be inspected for the defective insulation.

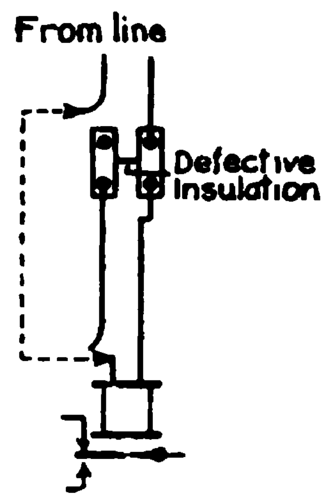

Fig. 149

454. If after testing with both wires disconnected outside the arrester the voltage across the circuit is still found to be low, the wires should again be connected and if convenient a voltage test made at the joints where the rubber covered wires are connected to the line wires. However, if these joints are not easily accessible, this test may for the present be omitted, especially if the line wire is covered and the joints well taped.

The maintainer should now proceed towards the battery observing the condition of the line, that is, whether it is crossed or broken at any point.

455. If the circuit is carried through any contacts between the relay and battery locations, it is advisable to stop and note that they are properly closed and, if convenient, take a current reading around them preferably *outside* of the lightning arresters, as shown in Fig. 150.

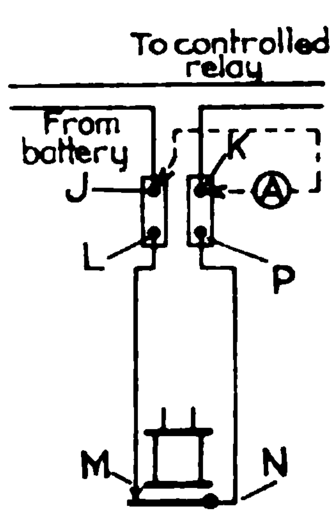

Fig. 150

456. If a reading near the normal current is obtained, it indicates that there is high resistance in the circuit between points J and K where the leads of the meter are attached. The lead should now be taken from one of these points, for instance J, and touched, successively at points L, M, N.* and P. If the readings all remain practically the same it, of course, indicates that the unusual resistance is between P and K, that is, in this arrester, where a closer test may be

*In this and similar diagrams, the points here represented by M and N will be understood to indicate the binding posts of the relay, or the wires directly attached to them.

made if desired, by touching on the various parts of the arrester which carry current.

457. If a noticeable drop should occur between any two points, for instance M and N, it would be well to connect this lead from the meter to the point where the last high reading was obtained (in this case M) and take the other lead from K and touch to point N, where a high reading will indicate that the undue resistance is in the relay contact or its connections.

458. In some cases, especially if the resistance of the controlled relay is quite high, it may be found more desirable to use a voltmeter instead of an ammeter for this test. The reading obtained in this case will be the drop in voltage around any resistance that may be in the circuit at this location and should normally be very low. If any considerable reading is obtained it, of course, indicates that the trouble is between the points where the meter leads are in contact with the circuit.

459. Assuming that no improper resistance or other defect has been found on the circuit, before reaching the battery, a voltage reading should be taken across its terminals to insure that it is not open. If a very low reading is obtained it indicates that there is high resistance at some point in the battery or its connections (that is, provided it is not exhausted or polarized) and the cells should be tested separately and in consecutive pairs as described in Art. 331. This will ordinarily locate the trouble in some cell or connection.

460. If the battery appears to be in good condition and a normal voltage is obtained, or a fair voltage, that is somewhat below normal, the ammeter should be connected in series, close to the battery and its action observed.

If the voltage was *below* normal and the ammeter now shows a reading *below* normal, it indicates that the battery is not as good as it appears to be, and a closer inspection is desirable. As a check on this conclusion, it is advisable to connect the voltmeter to the battery terminals and *short-circuit* the battery for three or four minutes, after which the shunt should be re-

moved without disconnecting the meter, and a reading taken at once. If this reading is considerably lower than that taken before the battery was short-circuited, it is an indication that the battery is in poor condition.

461. If the voltage was normal or somewhat above and the ammeter, when cut in, shows *no reading* or *very little,* it may be assumed that the circuit is *broken* or contains unduly *high resistance* at some point.

If the voltage was normal, or nearly so, and the ammeter shows a reading somewhat *above* the normal current, it indicates that there is a *shunt* of *considerable resistance* on the circuit. However, if the ammeter shows a reading *considerably above* the normal current, it indicates a *shunt* of *low resistance* on the circuit.

462. *Break or High Resistance in the Circuit.* If, by the tests made at the battery, it appears that the circuit is *dead open,** it may be found advisable to use a magneto. A magneto test may be started at any point by placing the instrument in series with the circuit, all connections being closed. If the bell will not ring when thus connected, it is very good evidence that the circuit is open.

463. If it is desired to test a length of line between two locations by this method, it is advisable first to get a ring through the controlled relay as shown at location A, Fig. 151, then con-

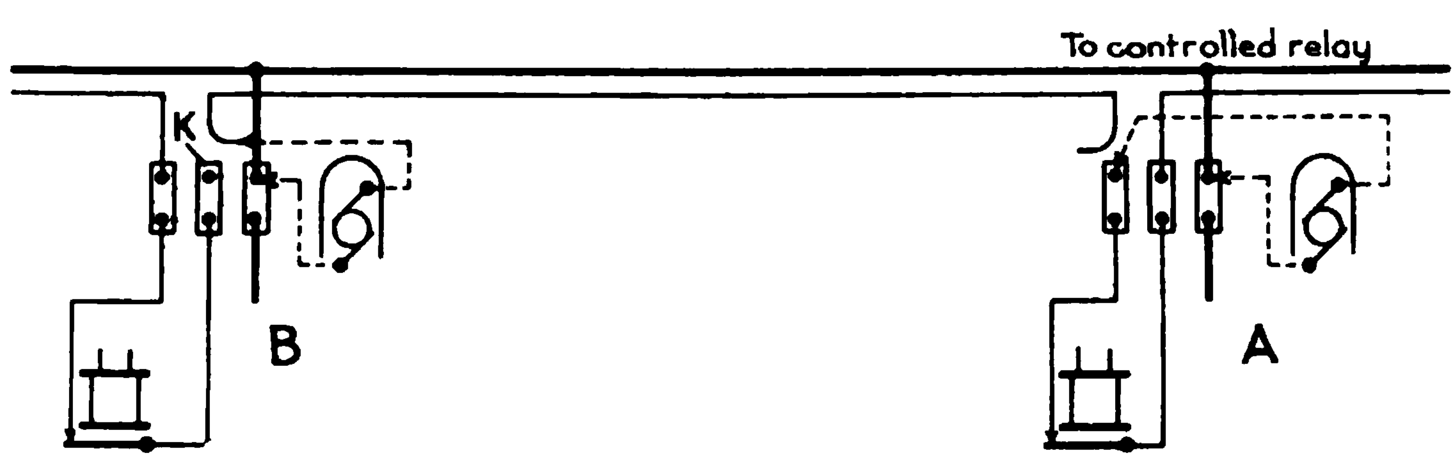

Fig. 151

nect up the circuit as usual at this location and go to location B the magneto being connected there as shown. If the bell fails

*See Art. 388.

to ring when thus connected at location B, it of course shows that the circuit is open between the two locations. If now it is desired to test along the line the wire must be left disconnected at K while the test is being made.

464. Another method frequently employed is shown in Fig. 152. With this method the wire ordinarily connected at point

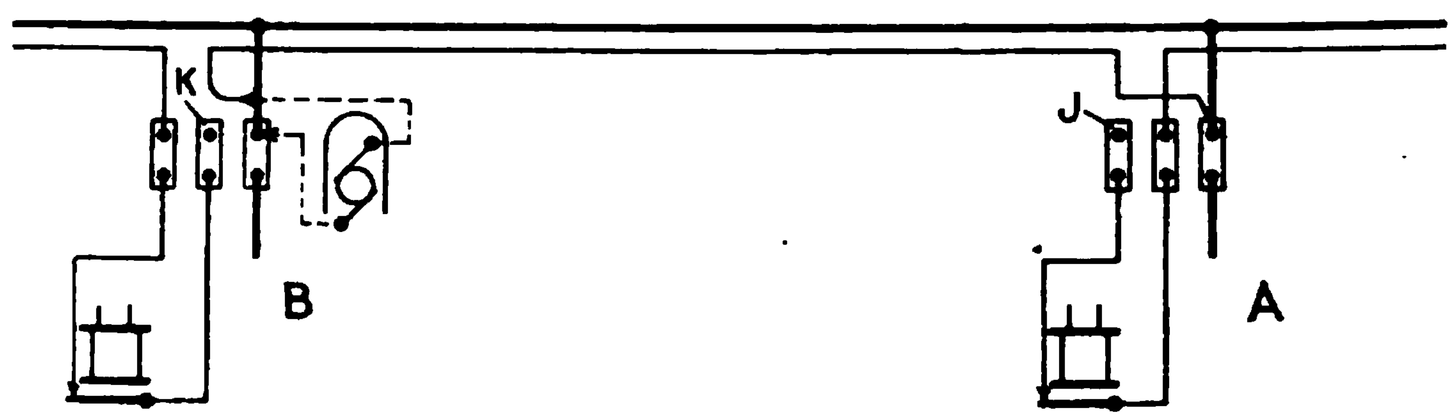

Fig. 152

J is disconnected and connected to the other side of the circuit as shown. The magneto is then connected as indicated. If desired, the magneto may be used at location A, the connections at B of course, being arranged as shown at A.

465. Another method for testing for a break or for high resistance, of course after the battery test is completed, is to make a voltage test at the next available point nearer the controlled relay.

If, as is frequently the case, there is a controlling relay near the battery, the test may be commenced at this point. A common arrangement is illustrated in Fig. 153, in which a voltmeter test is made *outside* of the lightning arresters, as shown.

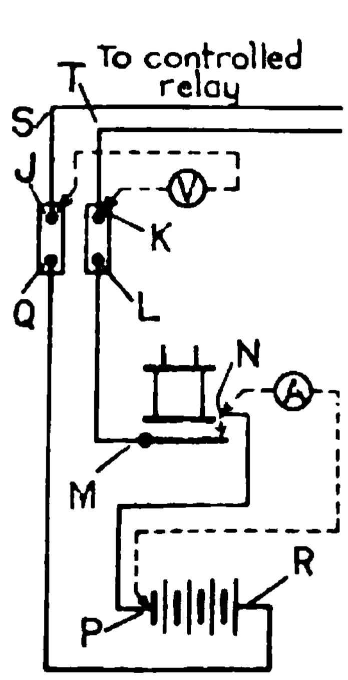

Fig. 153

A low voltage at this point shows that the trouble has already been passed and one of the meter leads should be left attached to the circuit, as at point J, while the other lead, shown attached at K, should be removed and touched successively at points L, M, N and P.

If a normal reading is obtained at any of these points, it of course indicates that the defect in the circuit has been passed. For example, if the reading at L is normal, the trouble must be in

the arrester between K and L; if the reading is low at M and high at N, the defect is, of course, in the relay or its connections.

If the voltage between points J and P is low, the lead should be left attached at point P and, the one taken from J and touched at Q, where a high reading, of course, shows the defect to be in the arrester, and a low reading, that it is in wire Q—R.

466. If the trouble is thus located between any of these points, for instance N and P, a check may be obtained by attaching the ammeter as shown, which if the circuit is entirely broken should show the normal current reading of the circuit; if the circuit is not broken but contains high resistance, this reading may be somewhat less than normal.

467. If the defect is found to be in a wire which is in trunking or otherwise not readily accessible, it is well now to connect a temporary wire in place of the ammeter, thus getting the circuit into operation at once, after which the permanent repairs may be made.

468. If with the voltmeter connected at J and K a normal reading is obtained, it of course, shows that the break or high resistance is nearer the controlled relay.

469. If joints S and T, where the rubber covered wires are connected to the line wires, are convenient, it is well to take a voltage reading there, especially if the circuit does not pass through any contact between this location and the controlled relay. In this and similar cases, it is often desirable, when convenient, to test these rubber covered wires separately. That is, first, with the meter connected from J to T which will show the condition of wire K—T, and then, if that is shown to be intact, between S and T. By following this course, the opening of a taped joint may often be avoided.

If, however, these joints are not easily accessible, or are made onto covered line wire and well taped, and there is a controlling instrument between this point and the controlled relay, it may be well to go at once to this intermediate point especially

if one side of the circuit is carried on a common wire, which is also accessible at that point, as is frequently the case.

470. Assuming that the intermediate point is the location of a controlling relay, the voltmeter tests illustrated in Fig. 154 should be made.

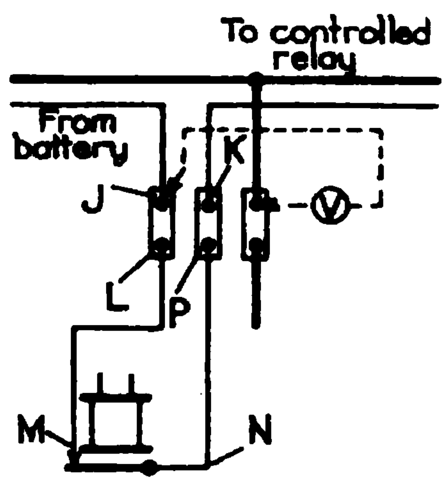

Fig. 154

If a normal voltage is obtained with the meter connected as shown, it indicates that the circuit is in good condition between the battery and this point. The meter lead should now be taken from point J and touched at point K. This is, of course, a check on the ammeter test described in Art. 455, and should not be necessary if that test was properly made. Any marked difference in the readings obtained at J and K, will, of course, indicate a break or high resistance in the circuit between these two points and should now be located by touching the same meter lead, to points L, M, N and P, and, if necessary at intermediate points between them, in a manner similar to that described in Art. 465. A normal voltage at K, of course, shows that the break or high resistance is further on towards the controlled relay, while a low reading at J indicates that the trouble is back towards the battery and has been passed. In the latter case, the circuit between this location and the battery must now be examined more carefully, and voltage tests across it taken as closely as practicable, the first points usually being where the rubber covered wires are connected to the line wires.

If by testing at the ends of the rubber covered leads it is found that they are in good condition and the trouble is therefore on the line, it is advisable to begin testing this about half way between the two points where the high and low readings were obtained.

471. If other circuits using the same common wire are working properly it may be assumed that that portion of the circuit is in good condition.

472. Bare wire may, of course, easily be tested at any point

by rubbing the surface bright with emery cloth or sand paper (care being taken not to remove the galvanizing from iron wire) and connecting the voltmeter at these points, one on the common and the other on the control wire.

473. If covered line wire is employed, the covering must, of course, be removed sufficiently to allow contact, and as it is desirable to do this at as few points as possible, it is best to make the tests at points where the common wire can be reached from one of its taps, as at relays, batteries, etc., if there are any within the length to be tested.

474. By making the test in the center of the length in which the trouble exists, this length will be reduced one-half every time a test is made, and thus the length, where it is possible for the defect to be, is reduced to a span, which if necessary may be cut down and repaired. It is, of course, usually necessary to cut the wire at one end of the span only.

475. Defects of this kind are most often found in joints in the wire. If there is a joint between iron and copper wire, it is almost sure to develop resistance unless it has been very carefully soldered. Therefore when making tests it is well to note the position of joints and select the locations for tests accordingly.

476. When testing on covered line wire where it is necessary to cut through the insulation, it is desirable to make it on the side of the insulator towards which it is thought the trouble is most likely to be,* about 1½ or 2 ft. from the end of the tie wire. The knife should be held at about the same angle as if sharpening a pencil. This will prevent it from *nicking* the wire and will also leave a "lip" of the covering which will assist in repairing the cut after the test is completed.

477. Covered wire sometimes breaks inside the insulation but does not fall, the covering being strong enough to hold it

*This will, of course, in many cases be a matter of guess work, but may be judged by the number of joints or other possible cause of trouble that may be on either side of the point where the test is being made.

up, frequently with very little more sag in the span than usual. This is most likely to occur near the insulators, therefore, if the possible location of the defect is confined to a length of wire which has no joints, a break of this kind may be looked for near any of the insulators. In such instances it may be found desirable to test on *both* sides of an insulator. For example, if in Fig. 155 it is found, when testing at point A, that the trouble is in the direction shown by the arrow, it may be well, especially if the possible location of the trouble is limited to two or three spans, to make another test at point B, as the wire in such a case, is as likely to be broken near this insulator as any other.

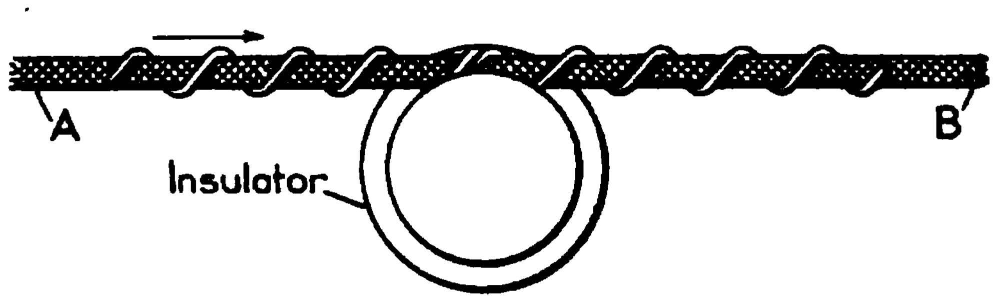

Fig. 155

478. If a break is thus located between these points by the voltmeter, it is well to check the test by connecting an ammeter from A to B, which should show a reading equal to the normal current in the circuit.

479. After the testing and repairs are completed, all cuts that have been made in the insulation should be filled with P. & B. compound and the insulation thus secured in its proper position, after which the outside of the insulation should be entirely coated with the compound for a space of about 2 in. each side of the cut, and a half lapped layer of friction tape applied over the length thus coated. The outside of the friction tape should then be painted with the compound.

All joints from which taping has been removed should, of course, again be taped and painted as described in *Line Construction.*

480. If, when testing as described in Art. 470, it is found that the break or high resistance is further on towards the controlled relay, the same method will, of course, be followed at the next location where the circuit is passed through a contact, coming back and testing out the line if necessary.

or moving on towards the controlled relay until the defect is located and repaired.

481. If at any location where the circuit passes through a contact, there is no tap from the common wire, or if the circuit has a separate return wire (which usually runs straight through) it may be found desirable to run a temporary tap from it to the voltmeter, using this instead of the common wire, shown in Fig. 154.

482. *Shunts.* If when testing as described in Arts. 460-461, it is found that there is a shunt on the circuit, and there is a controlling contact near the battery, as in Fig. 156,* it may be found convenient to leave the ammeter in series with the battery, as shown, while testing at the relay.

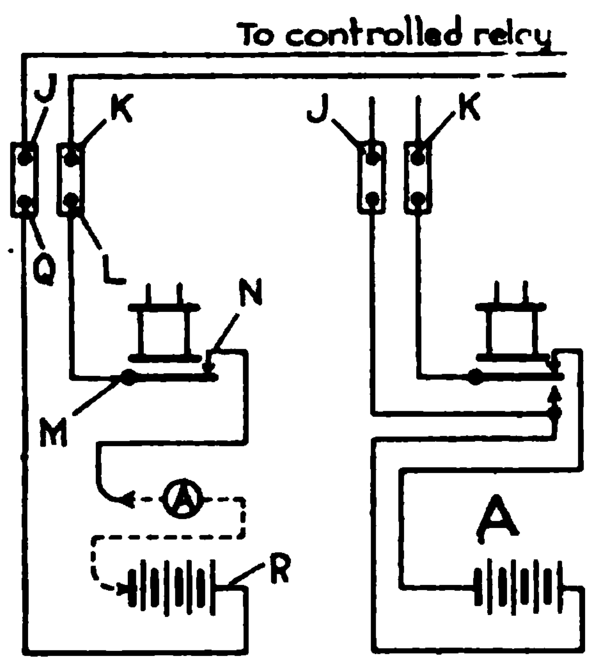

Fig. 156

483. The wire should now be disconnected at point N, noting the effect on the reading of the ammeter; if the circuit is in good condition between the battery and relay, the pointer will of course, go to zero; however, if it does not do so, the shunt is in this length of wire.

484. If the ammeter shows no deflection when the wire is disconnected at point N, indicating that the shunt is beyond this point, this wire should again be connected and the wire disconnected at K. A reading obtained when this wire is disconnected, shows defective insulation in lightning arrester K--L, wire L--M or the relay, the last named condition being more likely to occur when the other side of the circuit is carried to the relay, as for instance, in the case of a back contact, as illustrated in sketch A, or when a common wire is employed and connected to another binding post on this relay. In order to determine which of these parts of the circuit is defective,

*It will be observed that this arrangement is a duplicate of that shown in Fig. 153.

the wire is left disconnected at K, and the wire disconnected from the relay at M. If the meter still continues to show a current reading after this wire has been disconnected, the relay is defective, but if not the trouble in wire L—M* or arrester K—L, and can be located more closely by connecting the wire at M disconnecting at L, the results being judged as already described.

485. If, when the wire is disconnected at K, the pointer of the meter goes to zero, showing that that side of the circuit is in good condition from the battery to and through this arrester, this wire should be replaced, and a similar test made with the wire disconnected at J, which will give an indication of the condition of wiring and arrester between points R and J, and may be further tested by disconnecting at point Q.

486. If it is found that the shunt has been caused by a ground, for instance, in one of the lightning arresters, the circuit will of course work properly when this ground is removed, but it should be remembered that there is still a ground on the *other side* of the circuit, which should also be removed; that is, of course, unless that side is on a common wire which it is the practice to keep permanently grounded.

If the remaining ground is on a common wire, which is of considerable length, this ground may be quite a distance away from the circuit on which the failure occurred.**

487. Assuming now that no trouble has been found at the battery location, that is, that by disconnecting at either J or K, the ammeter in series with the battery goes to zero, the test must be carried on nearer the controlled relay, all wires being left connected as usual.

488. If there is a controlling contact between this location and the controlled relay, it is well to proceed to it and connect the

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*If this wire is simply a short flexible lead, as in a relay box, its condition can readily be determined by inspection.

**See Art. 589.

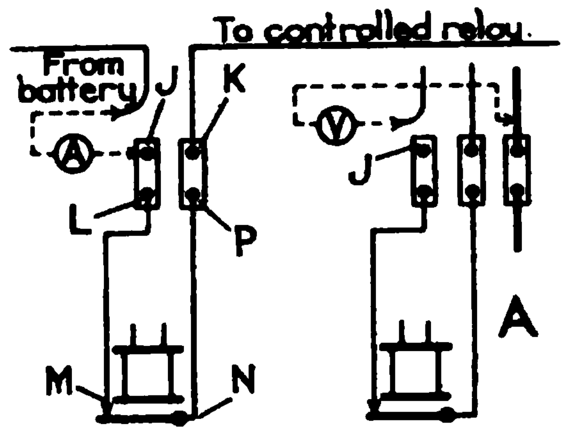

Fig. 157

ammeter as shown in Fig. 157, in which it is assumed that the controlling instrument is a relay.

489. If the current reading at this point is approximately the same as that obtained at the battery, it indicates that the control wire to this point is in good condition. With the meter still connected as shown the wire should now be disconnected from the arrester at K. If there is no defect in the instruments or wiring between the lightning arresters at this location, the pointer of the meter will of course, at once go to zero when this wire is disconnected, thus indicating that the shunt is further towards the controlled relay. If, however, the reading remains the same or drops only part way to zero, the wire should be left disconnected at K for the present, and the wire disconnected at point N. If this causes the pointer to go to zero, it of course, shows that there is trouble in wire N—P, or in the arrester P—K. If, however, the meter still shows a current reading the wires must be disconnected at M and L successively, the results obtained being judged as before. If with the wire disconnected at L, a reading is still obtained, it of course, shows that the arrester J—L is defective.

490. If when the ammeter is connected as shown no reading is obtained or one much less than at the battery location, it indicates that the shunt is back towards the battery.

It is advisable in such a case, if convenient, to make a check with the voltmeter as shown in sketch A, in which a low reading will confirm the conclusion that there is a shunt between point J and the battery location.

491. If the rubber covered wire between point J and the line wire is in plain view it should now be closely inspected so as to be sure that its insulation is not defective at any point. If it is concealed or in a cable with other wires a test should be made at the joint where it is connected to the line wire by disconnecting the rubber covered wire from the line wire and

placing the ammeter in the circuit at this point with the wire still disconnected at point J. A current reading, thus obtained, of course, indicates that the rubber covered wire is defective. If no reading is obtained, the trouble is nearer the battery and a similar test must be made at the battery location, at the joint where the rubber covered wire is connected to the line wire. When leaving the intermediate location, the circuit should be left open, preferably at the joint between the rubber covered wire and line wire, but if that cannot again be easily reached, as when on a pole, it may be connected temporarily and the wire left disconnected at point J, in order that when the defective condition is remedied, this portion of the circuit may be quickly placed in service.

492. If the rubber covered wire at the battery location for any reason appears to be more likely to be defective than at the intermediate location, as for instance, by running a greater length under ground, it may be well to make the test at the battery location first.

493. The trouble will probably now be found in the rubber covered wiring at one location or the other as a shunt on the open line wires is quite rare, except in case of crossed wires which can easily be observed from the ground. Where bare line wires are employed, it occasionally happens that a piece of fine wire may lodge across them and not be noticed. Cases have been known where wires have been maliciously grounded or crossed by fine wire which was concealed as much as possible. It is of course, understood that the wires are clear of trees, etc., or well insulated from them. In case the wires pass through trees which cannot be trimmed, the insulation may have become chaffed off, thus resulting in a ground.

494. If, however, the tests show that the shunt is on the line which appears to be clear, the circuit at the battery location should be connected as usual, and the control wire cut and the ammeter inserted about half way between the two locations, which will show in which half of the length the shunt is. If towards the battery it may be well to leave the wire open at

this point until another cut is made, but if towards the controlled relay it should of course, be closed. The line should be cut near joints, if possible, so as not to unnecessarily increase the number of joints in the line.

495. Before cutting the line it may be desirable, especially if any of the tests have been doubtful, to test it, when both ends are disconnected, with a magneto, as described in Art. 448.

496. Another test must now be made, cutting the line in the center of the length still indicating the shunt, and so on until its possible location is limited to one pole or span, which can be examined as closely as necessary.

497. If, when testing at the location of the intermediate controlling contact, the readings indicate that the shunt is further on towards the controlled relay, the tests will of course be carried on in that direction, first at any intermediate contacts, the same methods being employed as already described, and finally on the line with the circuit open at the controlled relay.

498. If when a shunt in the wiring or in an arrester is indicated by any of the tests, it is desired to get the circuit into operation before making a further inspection, a temporary wire may of course, be used as described in Art. 449. However, care must be taken not to allow such a wire to bridge any of the *controlling contacts* in the circuits, as a dangerous condition might thus be produced.

499. In some instances where the wire to be tested is of considerable length, especially if there is another *good* wire available for the purpose, it may be found advisable to make a *Varley loop** or *Murray loop** test when a reliable Wheatstone Bridge or other suitable instruments are obtainable.

500. *Battery at Other Locations.* If the battery is not located at the extreme end of the circuit, as assumed in the foregoing tests, the method of testing must be modified accordingly.

*Described in **Magnetism and Electricity**.

501. It will now be assumed that the battery is situated at the *same* location as the controlled relay, as illustrated in sketch A, Fig. 158. If with this arrangement, a low voltage is obtained at the terminals of the relay, and by making the tests described in Art. 451, the relay appears to be in good condition, a piece of wire should be touched across the circuit at points A and B, while the voltmeter is still connected in multiple with the relay. If this fails to produce a normal reading on the voltmeter it indicates that the trouble is at this location. In some instances, a voltage may thus be obtained which is sufficient to pick up the relay; but unless a *full normal* reading, or higher, is obtained, the test wire should now be removed and the battery tested as described in Arts. 459-461.

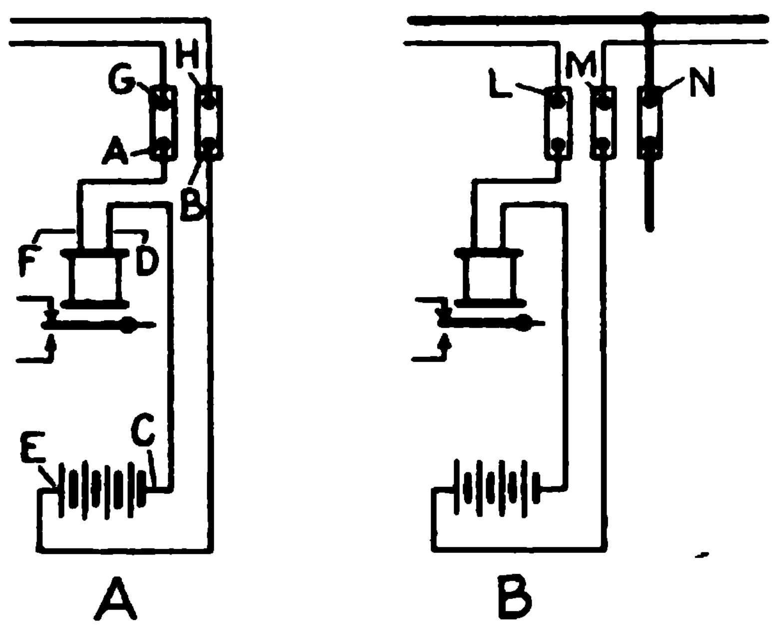

Fig. 158

502. If the tests show that the circuit is shunted, it is probable that the wire between points C and D is poorly insulated at some point. A temporary wire may now be put in use, while the permanent wiring is being inspected. If as may occasionally happen, the relay does not work properly when the temporary wire is connected up, it indicates that there is defective insulation in the relay.

503. If the tests at the battery show that the circuit contains a break or high resistance, a test wire connected between C and D, E and B, or A and F, will show which of these wires is defective.

504. If the full normal voltage, or higher, is produced at the terminals of the relay when the test jumper is touched across points A and B, the test jumper should then be bridged across the circuit at points G and H. If this does not produce approximately the same reading on the meter, there must be a break or high resistance in one of the arresters.

If, however, approximately the same result is obtained at points G and H, it indicates that the break or high resistance is beyond these points. A reading should now be taken with the voltmeter connected from G to H and the reading carefully noted.*

505. If convenient, a voltage reading should now be taken across the line at the joints where the rubber covered wires are connected to the line wires. If this reading is *much lower*** than that obtained at points G and H, it of course, indicates that the trouble is in one of the rubber covered wires, but if the reading remains approximately the same the trouble must be further out on the circuit.

If these joints are not within easy reach, or covered wire is employed, and the joints taped, this test may for the present, be omitted, the maintainer proceeding at once to the nearest controlling contact.

506. At the location of this contact, ammeter readings should first be taken as described in Art. 455. If no trouble is located by these tests the voltmeter should now be connected as shown in Fig 159, in which it is assumed that the other side of the circuit is on a common wire which has a tap into this location as indicated. If the reading thus obtained is only a small percentage below that obtained between G and H, Fig. 158, it may be assumed that the trouble is still further from the location of the battery and controlled relay. If, however, there is *considerable drop* in this reading it indicates that the trouble has been passed. As a check on the ammeter tests just mentioned, the meter lead should now be taken from point A and touched at point B; if the two readings are approximately the same, it may be assumed that the trouble is between point B and the point where the last test was made at the location of the battery and controlled relay.

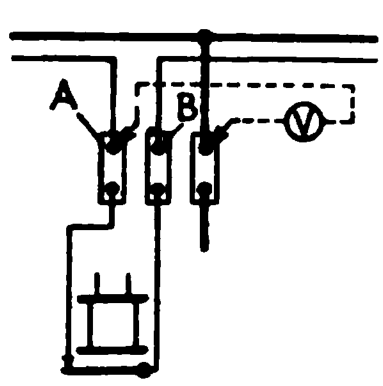

Fig. 159

*In case a voltmeter having a suitable scale is not at hand this reading may be taken with an ammeter, and used for comparison as hereafter described.

**These readings will of course drop slightly as they are carried further along the line, on account of its resistance.

507. In such a case, the rubber covered wires should, of course, first be tested, comparing the readings with that obtained between points G and H, after which the tests will, of course, be carried onto the line if necessary.

508. In case the other side of the circuit cannot easily be connected to, as shown in Fig. 159, or in case such tests indicate that the trouble is further from the battery, the maintainer should proceed in that direction repeating the tests just described at other controlling contacts until an indication of the trouble is found or until he reaches the end of the line. If after testing at the farthest relay he has not located the break or resistance he must return to the contacts at which it is assumed that he has omitted to make the test described in Art. 506, connect to the other side of the circuit* and make this test, which will direct him either toward the battery or away from it.

The magneto tests described in Arts. 462-464 may, of course, be employed in testing for the trouble just described.

509. If the circuit is carried through controlling contacts to the right as well as to the left of the battery location, as indicated in sketch B, Fig. 158, and it is desired to determine in which direction the trouble lies, tests may be made as follows: Assuming that the other side of the circuit is a common wire with a tap at this location as shown, the ammeter or a test jumper is touched across, first from L to N and then from M to N; in one of these tests the relay should pick up, the ammeter, if used, giving a considerable reading. The energizing of the relay will show that the defective portion of the circuit is bridged.

Care should be taken, when making these and similar tests, not to leave the jumper or meter connected any longer than is necessary to observe its effect, and *never* to go away leaving it connected, as it is evident that when it is so connected, one or more controlling contacts are bridged, which might result in a dangerous condition.

If the other side of the circuit cannot easily be reached, it may be advisable to make the ammeter tests at the controlling contacts (Arts. 455-458) before making the tests just described.

*See Art. 481.

510. In Figs. 160-161, are illustrated two other arrangements which are frequently met with. If in Fig. 160 a test at the battery shows a break or high resistance in the circuit, and the instruments and wiring at location B appear to be in good condition as indicated by a normal voltage or higher across the circuit at points J and K, the voltmeter should be connected as shown; that is, if the other side of the circuit is readily accessible. If

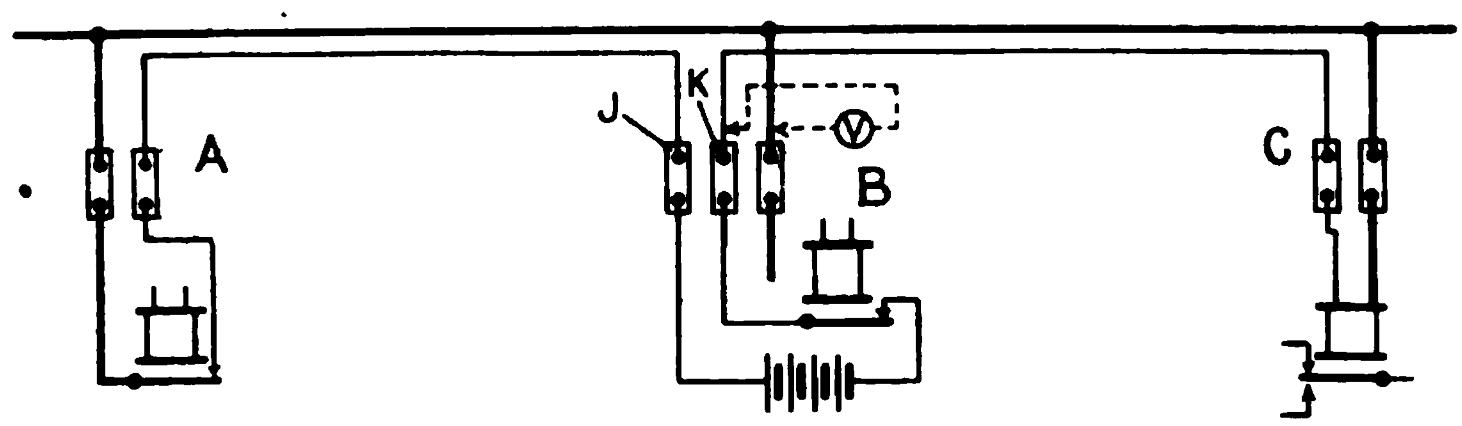

Fig. 160

a voltage equal to or above the normal reading, is thus obtained, it indicates that the trouble is towards location C, and if much below normal, that it is towards A. If towards C, it may now be located as described in Art. 462. If towards A, the meter lead should be disconnected from K and touched on J, this reading being carefully noted and used for comparing with other readings taken when testing towards location A, as described in Arts. 505-508.

511. If, however, the other side of the circuit is not easily accessible, it is well first to go to location A, and make an ammeter test there and at any intermediate contacts which there may be between B and A, also observing the condition of the line. If this does not locate the trouble, a tap from the other side of the circuit at location B should be made in the most convenient manner possible, and the test conducted as just explained. If the other side of the circuit is not accessible at this location, but may conveniently be reached at the location of a contact between B and C, it may be well to first make the voltmeter test at such a location.

512. In case the current is found to be shunted out of the relay the trouble must, of course, be either at location B or C or between them, and will be tested for as described in Art. 482.

513. If, in Fig: 161, a test at the battery shows a break or high resistance on the line, the test will, of course, be conducted

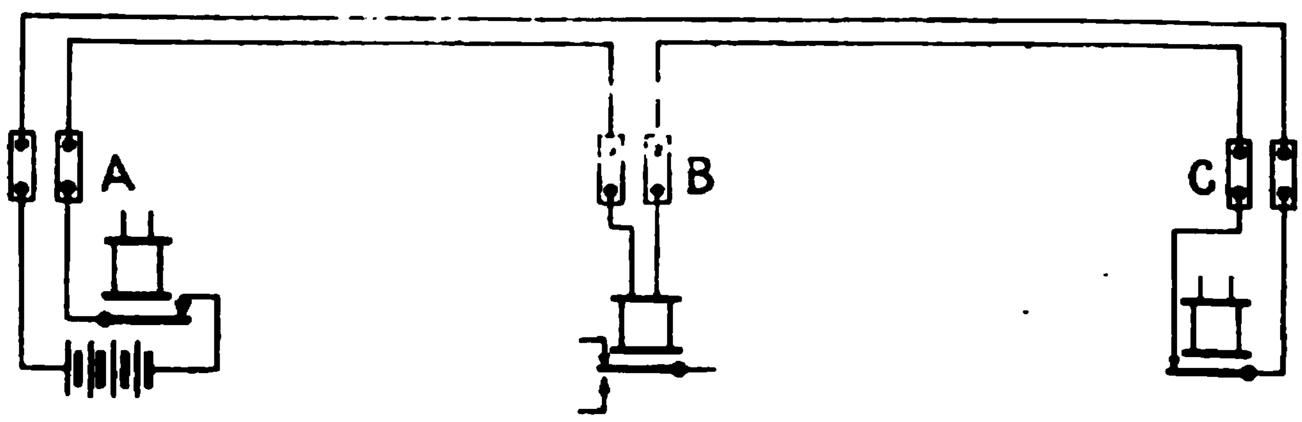

Fig. 161

between locations A and B as described in Art. 462 and between locations B and C as described in Arts. 504-509.

514. A shunt which will de-energize the relay can, in this case, only happen at location A or B, or between them, and will be tested for as described in Art. 482.

515. *Clear Failures.* If the controlled relay of a normally closed line circuit fails to release properly when the circuit is opened at any of the controlling contacts, a dangerous condition is, of course, likely to result; therefore, in such a case, measures should first be taken to insure safety. For instance, if an automatic crossing alarm is controlled through a back contact of this relay, it is evident that when the alarm should operate it will fail to do so, and thus travelers on the highway will not receive proper warning; in such a case, therefore, steps should at once be taken to have the crossing guarded until the cause of the failure is remedied.

In many cases the maintainer may be able to guard the crossing while inspecting part of the circuit.

When the circuit is controlled through two or more contacts, train movements should, if possible, be observed, in order to ascertain whether or not more than one of these contacts fail to de-energize the controlled relay.

516. After taking the necessary precautions to insure safety, the controlled relay should be inspected to ascertain whether it is in good condition.

The control wire, in case a common wire is employed, or if

not, either one of the wires, should be disconnected from the coil of the relay. If it now fails to release, it is of course out of order.

If the armature does release and a low reading ammeter is available, it should be cut in at the other terminal of the coils. If any reading is obtained it shows that there is defective insulation in the relay. It is well when the meter is thus connected, to touch the wire which was first disconnected from the relay, to its own post thus energizing the relay and then removing it without jarring the relay. If when this is done the pointer of the meter goes to zero, it may be assumed that the relay is in good condition. If a low reading ammeter is not obtainable a similar test may be made with a voltmeter across its terminals. In case neither are available the wire should be touched to the terminal and carefully removed, if convenient using a short length of wire small enough to be quite flexible, which is attached to the terminal and the regular wire touched to the smaller, thus avoiding any jar on the relay which might cause it to release while current about as high as the drop-away was passing through the coils. If, however, the relay releases promptly when the wires are separated, it may be assumed to be in good condition.

517. If no defect is found in the relay, an ammeter or voltmeter should be connected in series at one of its terminals as shown in Fig. 162, and the wire disconnected at point A.* If the pointer of the meter now goes to zero, the wire should again be connected at A and a similar test made at point B, where a similar result will indicate that the insulation of the arresters and wiring between them and the relay is in good condition.

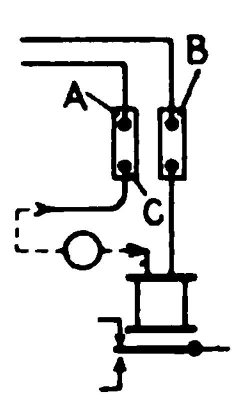

Fig. 162

If when the circuit is opened at either of these points the meter gives a reading, it of course, shows that there is defective insulation between that point and the relay. For instance, if when disconnected at A the pointer does not go to zero, it indicates that there is a ground in the arrester A—C, which is one of two grounds operating as explained in con-

*It is assumed that the battery is at the opposite end of the circuit from the controlled relay.

nection with Figs. 141-142, or in the wire between point C and the relay. If this wiring is in plain view as is frequently the case, its insulation may, of course, easily be inspected. If not, the wire should be disconnected at C, and if the meter then shows a reading it indicates that the wire is grounded and if not, that the ground must be in the arrester.

518. If no reading is obtained when disconnected at either point A or point B, it indicates that the trouble is beyond these arresters, and it is advisable now to make an inspection at the location of the nearest contact which fails to de-energize the relay, an ammeter or voltmeter being connected into the circuit as shown in Fig. 163. The contact should now be opened as, in this case by de-energizing the relay as shown, and if the pointer does not go to zero, it of course shows that there is defective insulation in lightning arrester K—L, wire L—M or the relay. The wire should now be disconnected at point M and if the pointer then goes to zero, it shows that the insulation in this relay is defective.

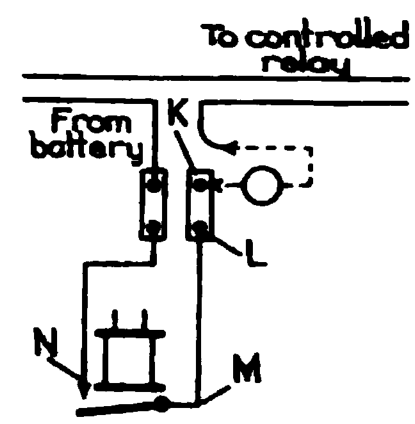

Fig. 163

If, however, the pointer does not go to zero when the wire is disconnected at M it should be left off the binding post, and also disconnected at L, which will in the same manner show whether the defective insulation is in wire L—M or in arrester K—L.

519. If no reading was obtained on the meter when the contact was opened it now indicates that there is poor insulation between point K and point A, Fig. 162.

If there are any controlling contacts between these points they should next be inspected. The wire should be left disconnected at K, Figs. 163-164 and the meter cut in as shown at point R, Fig. 164. A reading at this point shows that there is defective insulation between the meter and point K. The wire should now be disconnected at point S, and if the meter now gives a

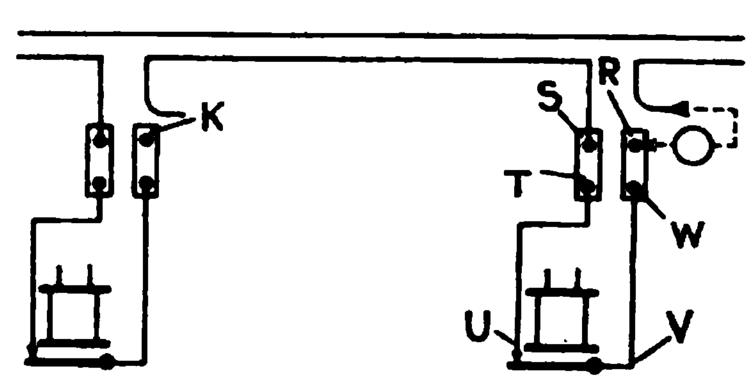

Fig. 164

reading it shows that there is trouble between points R and S, if not, that it is between S and K. If between R and S, it can be located by disconnecting successively at points T, U, V and W.

520. If the test shows that the trouble is between points S and K, the rubber covered wire from point S to the line may be tested by connecting up at all points, leaving the meter as shown, which will now give a reading, and then disconnecting the rubber covered lead from point S, where it joins the line. If a reading is now obtained, it will of course, show that the insulation of this rubber covered wire is defective, if not, that there is trouble towards point K.

521. The meter should now be taken out, and all wires connected at this location, the meter being taken back to the other location and placed in series, at the joint where the rubber covered lead from point K is connected to the line, the circuit still being left open, as shown, at K. A reading obtained here shows that the insulation of the rubber covered wire is defective and its absence, that the line is poorly insulated.*

522. If the last named condition is found the circuit should be left open either at point K or at the joint where this rubber covered lead is connected to the line (preferably at the latter point) and the meter cut in series with the line, selecting joints when possible,** first near the center of the length where a reading will, of course, show that the trouble is towards point K, and its absence, towards S; the remaining length should now be tested in the same manner until the defective insulation is discovered.

523. Another very good method of testing this length of line is to leave it open at *both* ends and then test with a magneto from this line to ground, which will probably produce a ring, then start in the middle cutting the line and testing

*If the rubber covered lead from K appears more likely to be defective than the one from S, it may be desirable to first test the former.

**See Art. 494.

for the ground each way with the magneto, and again dividing the remaining length as already described.

A satisfactory ground for the magneto terminal can usually be obtained on the rail or in any pool of water that may be convenient.

524. If with the meter connected as shown in Fig. 164 no reading is obtained, there must be defective insulation nearer the controlled relay, tests being made at any intervening contacts and the line wire between any two locations being tested if necessary, until the tests are carried to point A, Fig. 162.

In some cases, of course, a temporary wire may be used as already mentioned, to put the circuit in working order, while a portion of it is being examined.

525. After the defective insulation, on the control wire between the relay contact, Fig. 163, and the controlled relay has thus been located and repaired, it should be remembered that there must be defective insulation at another point in this or some other circuit (except in case of foreign current*), which must be located and repaired before the failure can be considered as completely remedied.

526. If the circuit is entirely independent, not being connected to any other, as by a common wire, this defective insulation must, of course, be at some point between the controlling contact, which failed to de-energize the controlled relay, and the battery, as may be seen in Fig. 141.

527. A very good method of locating this defect is to disconnect the control wire at the battery and test with a magneto when the contact in question is open, one terminal of the magneto being connected to this portion of the circuit and the other to ground. This will probably produce a ring** proving that there is a ground at some point along the wire.

The wire should now be disconnected from the relay at point

*Treated in Art. 594.

**The only instance in which this would not do so would be in the case of two crosses onto a parallel circuit one each side of the contact which failed to de-energize the controlled relay

N, Fig. 163, and the test repeated, and so on, until the portion of the circuit on which it is possible for the ground to be, is limited to a length which may be bridged with a temporary wire, and examined as closely as necessary.

528. If a common wire is employed as part of the circuit, and no ring is obtained when testing as directed in Art. 527, it may be assumed that the current which energized the relay improperly came from some other circuit, which is connected to the same common wire, in a manner similar to that shown in Fig. 142.

In this case the lightning arresters on all the other circuits connected to the same common wire should first be examined, and if that does not locate any ground these circuits should be tested, one at a time, by disconnecting them from the common wire at each end and then testing for a ground with the magneto.

This should show which circuit is grounded and this circuit may now be further disconnected and tested as is found necessary.

529. It should be remembered that there may be grounds on more than one circuit all of which would help to cause such a failure, if all of the batteries have the same pole connected to the common wire. Therefore after one such ground has been removed and the circuit connected up and working, a test should be made with the magneto between the common wire and a good ground, in which case a ring will of course, indicate that there are still one or more grounds to be removed.

530. When testing with a meter as described in Arts. 516-522, the readings may occasionally disappear and return again, this being caused by the opening of one of the controlling contacts of a circuit whose battery is improperly supplying current through a ground or cross to the circuit being tested. For instance, in Fig. 142, if relay B when open had failed to deenergize relay A on account of current from battery C passing through grounds at points X and Y then the meter placed

in series with relay A to test this circuit, would show this current when relay F is closed but not when it is open.

When these changes occur they may sometimes enable the maintainer to locate the circuit from which the current is coming by noting the position of trains at such times.

531. When a clear failure occurs on a circuit, the battery and controlled relay of which are *not* located at the extreme ends of the line, the cause of the failure may be located in a manner similar to that just described, that is, first locating and remedying the defective insulation on the portion of the control wire between the contact which failed to de-energize the controlled relay, and that relay, and then on the part of the circuit between the controlling contact and the battery, or on another circuit. In some instances however, a different method of procedure may be more satisfactory.

532. If the battery is at the *same* location as the controlled relay, then after this relay has been found to be in good condition, the meter should be connected as shown in Fig. 165, and tests made with the wire disconnected at point A, as described in connection with Fig. 162. If this does not locate the trouble, the wire should be replaced at A, and disconnected at point B. If when this is done the meter continues to show a reading, it indicates that there is defective insulation between points B and C, which may be more closely located by disconnecting at D.

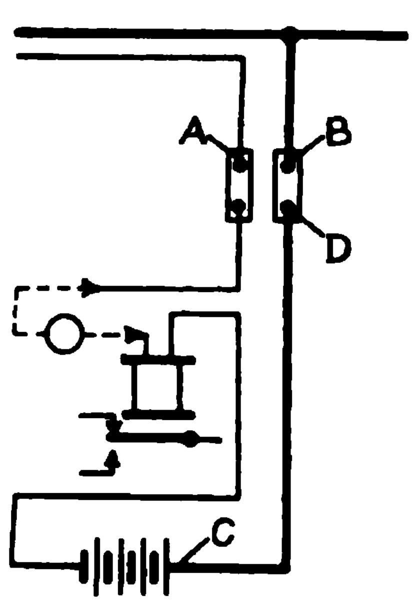

Fig. 165

If, however, the return is on a common wire, as shown, and it is the practice to keep this common wire grounded, this test is not likely to be of any value.

If there is one or more controlling contacts in both directions from the location of the controlled relay and battery,* it should be remembered that two grounds, one on each side of this location, might in some cases affect all of the controlling contacts, preventing any of them from de-energizing the con-

*See sketch B, Fig. 158.

trolled relay, while in other cases it might affect only part of the contacts in each direction, or those in one direction only. In case the last mentioned condition is found, and a ground is located in the direction of the contacts which have failed to operate the circuit properly, the corresponding ground is likely to be in either direction from the battery location.

533. After testing at the location of the contact which failed to de-energize the controlled relay, it is found that there is trouble on a certain section of the control wire, it must be remembered that the trouble may be caused by a cross onto the other side of the circuit as well as by a ground, and if employing a magneto, it is first necessary to determine whether the defective section of the control wire is grounded or simply in contact with the other side of the circuit.

534. In case the return for the circuit is on a common wire, as shown in Figs. 165-166, which has taps into the same locations where the circuit is carried through contacts, it is advisable to inspect these locations as soon as they are reached if any are to be passed when proceeding to the contact which failed to de-energize the controlled relay, as the cross is quite likely to be in the lightning arresters at such points.

In testing at such points, the meter should be cut in, and the wire disconnected at point J, as shown in Fig. 166, in which case, a reading indicates that there is trouble at this location, which may be located more closely by disconnecting the wires at points L, M, N and P, as already explained.

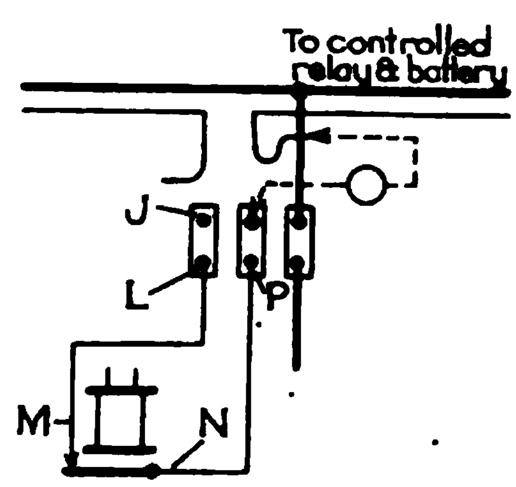

Fig. 166

535. When the battery is located at an intermediate point in the circuit, as shown in Fig. 160, the tests described in Arts. 516-530 should be used if the contact, which failed to de-energize the controlled relay, is between this relay and the battery.

536. If this contact is *beyond* the battery, the tests should be started at this contact, if the controlled relay and apparatus and wiring at its location, are found to be in good condition.

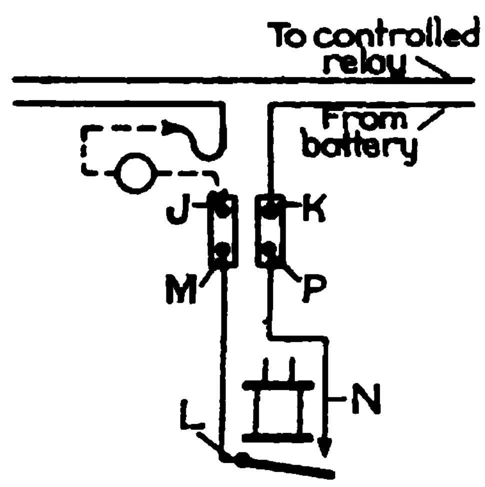

Fig. 167

the meter being cut in and the contact opened as shown in Fig. 167. If a reading is obtained on the meter when the contact is open it of course indicates that there is trouble at this point which may be located more closely by disconnecting at points L and M.

If no reading is obtained with the meter connected as shown, the wire should be connected up at J as usual, the meter connected in a similar manner at point K and the contact again opened, in which case, a reading will of course indicate that there is trouble between the meter and the contact which may be more closely located by disconnecting at points N and P.

537. If these tests do not locate the trouble, the wire should be left disconnected at point K, and the test taken up nearer the battery location. If there are any intermediate contacts the meter should now be connected at the first, as shown in Fig. 168, and if a reading is obtained the wire should be disconnected at S, with the meter still connected at R, as shown, in which case if the pointer goes to zero, it indicates that there is poor insulation between point S and point K, Fig. 167, and if not, that it is between points R and S, and may be located more closely by disconnecting at points T, U, V and W.

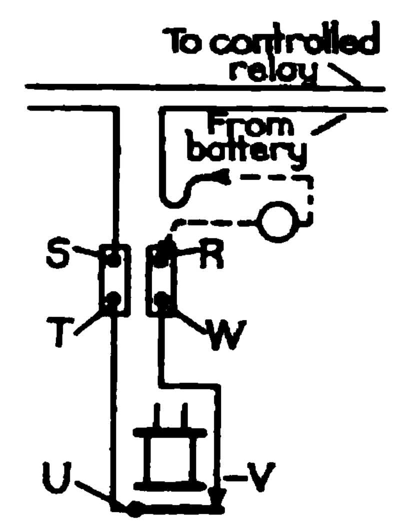

Fig. 168

538. If no reading is obtained at this location all wires should be connected as usual and a similar test made at the next contact location nearer the battery, and so on, until the battery is reached, where the meter should be connected as shown in Fig. 169, in which case a reading should be obtained,* unless the circuit is arranged as shown in Fig. 170, and the trouble is as explained in connection with it. The wire should now be disconnected at point A, and if the pointer

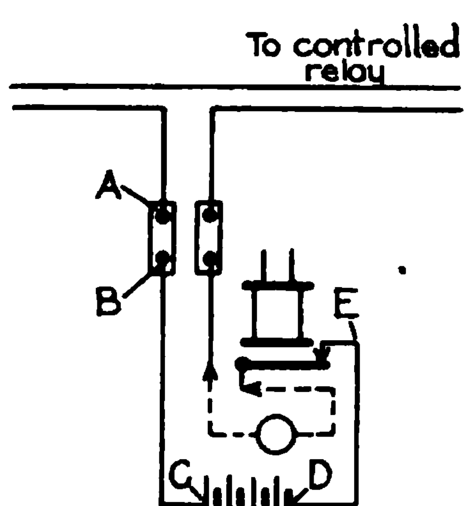

Fig. 169

*This reading may, however, be intermittent as explained in Art. 530.

goes to zero, it indicates that the trouble is between point A and the point where the meter was last connected before proceeding to the battery; if not, it shows that there is poor insulation between point A and the meter, which may be more closely located by disconnecting at points B, C, D and E.

539. If the trouble is between any two locations as point A, Fig. 169, and point R, Fig. 168, it is well to open the circuit at both of these points and test with a magneto.

540. In case there is no contact at the battery location the meter should be connected as shown at point F, in Fig. 170, where readings will indicate the same as when connected as shown in Fig. 169, the wires being disconnected at points A, B, C, D and E, if necessary, to locate the defective insulation. If no reading is obtained when the meter is cut in as shown at F, the wire should be left disconnected at this point, and the meter cut in at the location of the first contact in the direction of the controlled relay, as shown at point N.

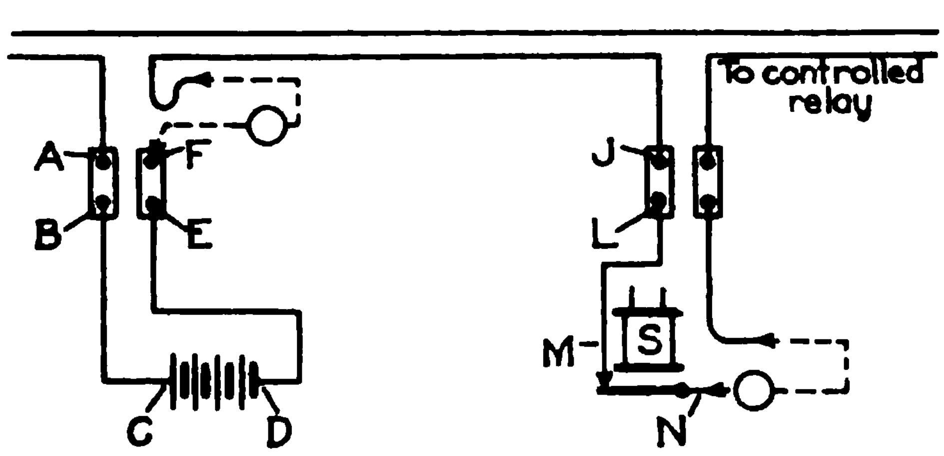

Fig. 170

As it is assumed that the contact which failed to de-energize the controlled relay is beyond the battery and that the opening of the contact on relay S does *not* fail to do so, then it is evident that the trouble must be between point F and the contact of relay S, and therefore a reading should be obtained with the meter cut in at point N, in which event the wire should be disconnected at point J; if the pointer of the meter goes to zero it indicates that there is trouble between points F and J, and if not, that it is between point J and the meter, which may of course, be more closely located by disconnecting at points L and M.

541. If the circuit is isolated* and the contact which failed

*See Art. 317.

to de-energize the controlled relay is further from this relay than the battery, as has just been assumed, the wire between the battery and this contact must of course either be *grounded* or *crossed* onto the other side of the circuit, and the tests just described for use between the battery and the first contact towards the controlled relay should be unnecessary.

542. A case which would cause an intermittent reading when the meter is connected as shown in Fig. 169, is illustrated in Fig. 171.

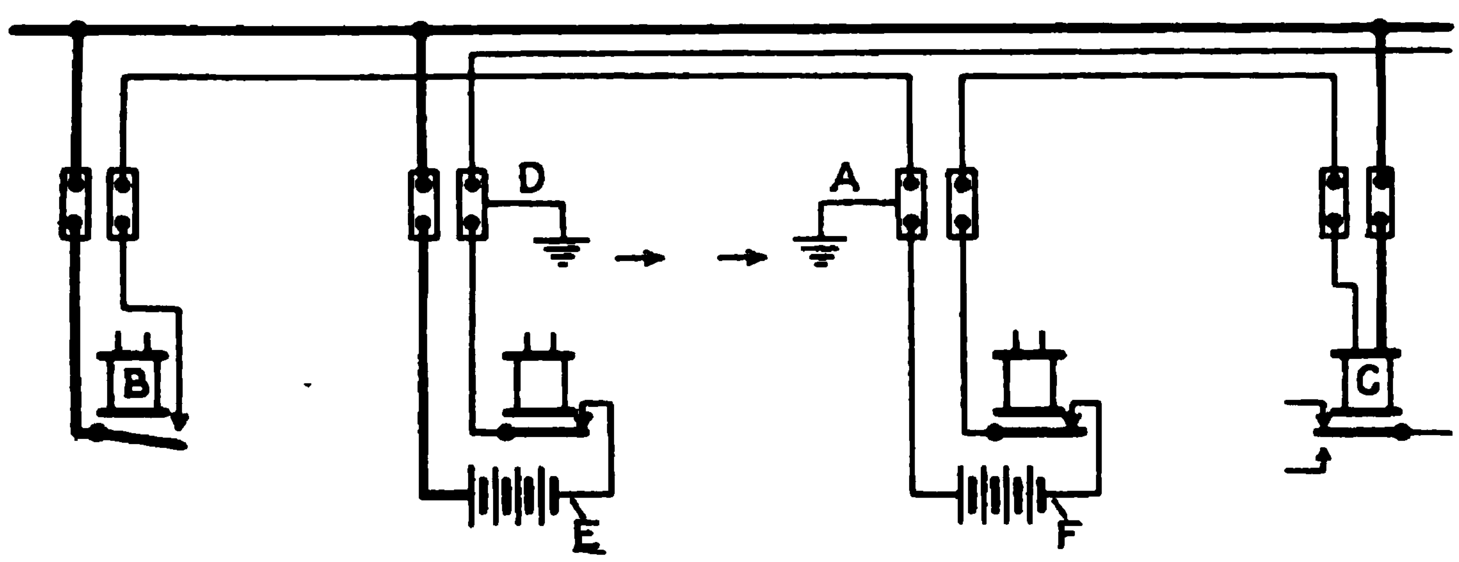

Fig. 171

If a common wire is used as shown in this illustration and a ground is located, for instance in lightning arrester A, there are two possible conditions which might prevent the contact on relay B from de-energizing relay C. One is a ground at some point on the common wire, and the other is a ground on the battery wire or control wire of some other circuit, as for instance in arrester D, the current from battery E passing through the earth as shown by arrows and working in series with battery F. Of course in order to produce this last condition the batteries if of equal voltage, or nearly so, will be found to have their polarity so arranged that they will *not* oppose each other; however if one battery is of much higher voltage than the other, it may overcome the latter, if they *do* oppose each other, and thus cause a clear failure.

543. When the controlled relay is not at the end of the circuit, but at an intermediate point, as illustrated in Fig. 161, then if the trouble is not found in this relay or at its location,

and the contact which failed to de-energize it is towards the battery, the tests described in Arts. 516-530 should be employed, and if in the opposite direction, the test described in Arts. 532-534.

544. In other circuit arrangements than those which have been shown, which will occasionally be met with in this class of work, the same general principles will apply for locating and removing the crosses or grounds which cause the controlled instruments in normally closed circuits to remain energized when controlling contacts are open.

545. In all cases it should be remembered that either the contact or contacts which fail to de-energize the controlled instrument are *bridged* or there is current from some *other source* coming to this instrument between it and the *nearest* contact which has failed to operate it.

546. Normally Open Circuits: If the relay, or other controlled instrument, of a normally open line circuit fails to pick up properly when a controlling contact is closed, any dangerous condition that might be caused by such a failure should first be guarded against as mentioned in Art. 515.

547. If there are two or more controlling contacts, it should, if possible, be observed whether the closing of any of them will energize the controlled instrument. If the instrument operates for any of these contacts, it may be assumed that the failure is caused by a break or high resistance in the branch of the circuit which goes to the contacts that failed, which should be located as described in Arts. 562-565.

548. *Battery and Controlled Instrument at Same Location.* If the controlled instrument fails to pick up for any of the controlling contacts, assuming that this instrument is a relay and that the battery is at the same location, a test wire, or if

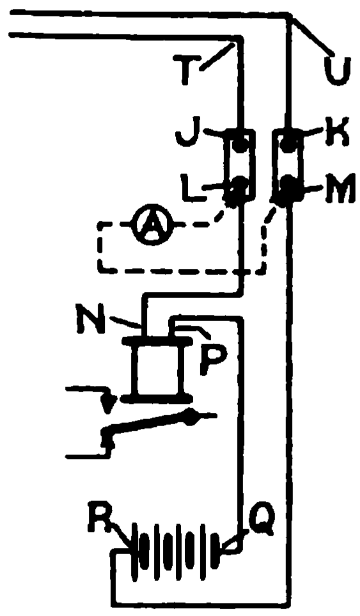

Fig. 172

convenient, an ammeter should be connected as shown in Fig. 172. If the relay picks up strongly, it may be assumed that the battery, relay and wiring to the lightning arresters, are in good condition. If an ammeter is employed, a reading somewhat above the normal current usually flowing when the circuit is closed, will confirm this conclusion. In such a case the test lead shown attached at point L should be changed to J, and if a similar result is obtained, it indicates that arrester J—L is in good condition, in which case, this lead should be left attached at point J and arrester K—M tested in the same manner.

549. If when the test wire or meter was first connected at points L and M, the relay failed to pick up, it of course indicates that there is trouble at this location. If a meter was employed and a normal reading or higher was obtained and the relay failed to pick up, the meter should be connected as shown in Fig. 173. If the reading now obtained is normal or above and the relay fails to pick up, it is evident that one or both of its coils are shunted. If a normal or slightly higher reading is obtained and the relay operates properly, it indicates that there is defective insulation between the wires, at point S, in which case wire L—N or wire P—Q, Fig. 172, (whichever is more convenient) should be disconnected at both ends, and a temporary wire connected in its place, until the defect is remedied.

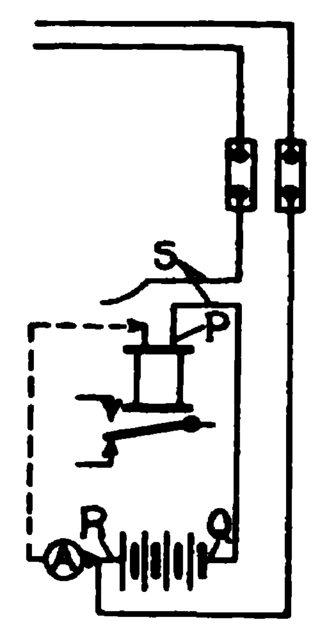

Fig. 173

550. If, with the ammeter connected as shown in Fig. 172, no reading or one much below the normal current of the circuit is obtained, it also indicates that the trouble is at this location. The meter lead Fig. 172, should now be taken from point L and touched at point N, with the other lead still attached at point M (or a test wire connected between points M

and N). If the relay now picks up it of course shows that wire L—N is defective.

551. If, however, a low or no reading is thus obtained, the test lead should again be attached at point L, and a voltage reading taken at the terminals, N and P, of the relay. If a normal voltage or higher is thus obtained, it of course shows that there is a break or high resistance in the relay. If this reading is below normal, the battery should be inspected and tested as described in Arts. 459-460, with a test wire connected at L and M.

552. If the battery is found to be in good condition and the tests show that there is a break or high resistance in the circuit, this defect must be either in wire P—Q or wire M—R, which can now be tested by connecting a test wire in multiple, first with one and then with the other.

553. If the tests at the battery indicate a shunt on the circuit, there must be defective insulation between these two wires, one of which should now be disconnected at both ends and a temporary wire used in its place, until the defective insulation is repaired.

554. If the relay picks up strongly and a good reading is obtained at points J and K, when testing as explained in Art. 548, it indicates that there is a break or high resistance in the circuit beyond these points. In this case the voltmeter* should be connected at the same points, and its reading carefully noted.

555. If there are two or more controlling contacts, the voltmeter should now be connected between joint T, where the rubber covered wire is attached to the line, and point K. If a lower reading is thus obtained, it of course indicates that wire T—J is defective, if not, the meter should be connected between joint U and point J, for a similar test on wire U—K. If a meter is not at hand these wires may be tested by employ-

*See footnote Art. 504 about use of ammeter instead of voltmeter.

ing a test jumper instead of the meter and observing the operation of the relay (which should, of course, pick up, in each case unless there is a defect.)

If both rubber covered wires are thus shown to be in good condition, the trouble should now be looked for beyond this point.

556. At the nearest contact to the controlled relay, which is in this case assumed to be a spring key, the voltmeter should be connected as shown in Fig. 174.* A low or no reading should now be obtained, showing that there is a break or high resistance between this location and that of the controlled relay. If there is any doubt as to whether the other contacts will operate the controlled relay, the voltmeter may be attached at joints A and B where a similar result will show that the trouble is on the line and has already been passed. The line must now be tested either by taking voltage readings, or with a magneto, as already described.

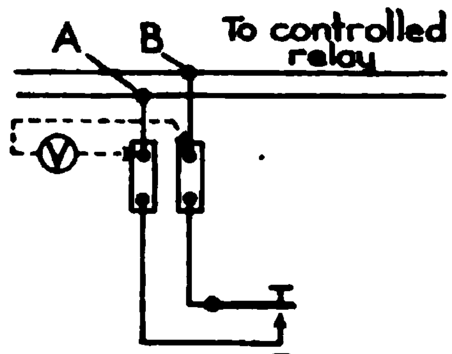

Fig. 174

557. If there is but one controlling contact the test of the rubber covered wires J—T and K—U, Fig. 172, may be omitted if it is not convenient to make them, the maintainer proceeding at once to this contact.

Assuming that the circuit is controlled through the back contact of a relay at this point, the meter should be connected as shown in Fig. 175. If this produces a reading only slightly below the one obtained between points J and K, Fig. 172, it indicates that the trouble is in the contact, or its connections within the instrument. As a check on this test, the contact may now be closed** and a fair reading should still be obtained, which would not be the case if this were in good condition.

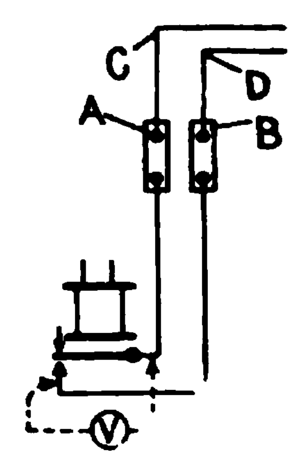

Fig. 175

*If no lightning arresters or terminals are used at this point, the rubber covered wires being brought direct to the key, this test should of course, be made at its binding posts.

**As this may close the line circuit and thus operate the apparatus connected with it, it may be desirable to have an understanding with those concerned (such as crossing flagmen, etc.) or to have a helper stationed at the controlled instrment, (as for instance in the case of a stick relay controlling a crossing alarm) to prevent its operation from hindering traffic on the highway. Of course in many cases it will be possible to *cut out* the apparatus operated by the controlled instrument, after the necessary steps have been taken to insure safety, until the trouble has been remedied. This condition should be guarded against in other tests hereafter given.

558. If when the meter is connected as shown in Fig. 175, no reading is obtained or one much lower than that between points J and K, Fig. 172, it indicates that the trouble is nearer the controlled relay. However, if any reading is obtained, it is well to close the contact, which if in good condition should cause the pointer to go to zero or very nearly so.

If such a condition is found, the meter should be connected between points A and B. If the reading thus obtained is much higher than the last, it indicates that the trouble has already been passed and may be located by closing the contact (or bridging it with a jumper) and then connecting a test wire in multiple first with one arrester and then the other, and then with the wires, noting which connection shunts the meter.

559. If the reading obtained between points A and B is practically the same as at the binding posts of the relay, and closing the contact affects it in the same manner the defect must be nearer the controlled relay and this test should now be repeated at points C and D, where the rubber covered wires are connected to the line wires, the indications being the same. If the trouble is thus located on the line, it should be tested as already described.

560. In cases where there is but one controlling contact and it is found more convenient to reach this contact before going to the controlled relay, the trouble may often be located at once by the tests just explained. If the defect is not found the readings obtained should be noted, to avoid, if possible, having to return to this location.

561. In cases where more than one contact is employed to close the circuit and the controlled instrument operates with some but not with others, the method of procedure varies somewhat.

562. If but one contact fails to energize the controlled instrument it is well to proceed at once to this location especially if it is not the one farthest from the controlled instrument, and test as described in Arts. 557-559, as the trouble is doubtless in this branch of the circuit.

563. In case it is the farthest contact from the controlled instrument, if convenient, it is well to inspect that location first, as the trouble may be there or in the line between it and the point where the branch to the next contact is tapped off. However, this may not be the case, as is explained in Art. 565.

564. In case the circuit fails to work for two or more contacts and not for any others, the contacts for which it failed must of course be those farthest from the controlled instrument, or else there are two or more causes of failure. Assuming then that they are those farthest from this instrument, the trouble may be caused by a break or high resistance in the circuit between these contacts and the next contact towards the controlled relay.

565. However, when one or more contacts at the extreme end of the circuit fail to operate it, the trouble may be caused by a weak battery or high resistance at some point in the circuit which weakens the current so much that the controlled instrument fails to operate for the contacts at a distance but continues to work for those nearer, on account of the shorter length of line to the latter.

Such a condition can sometimes be detected by observing the operation of the controlled instrument (or of an ammeter in series with it), which in such cases usually operates rather weakly when the nearer contacts are closed. If, however, the battery appears to be in good condition, and the controlled instrument operates strongly for the nearer contacts, this is sufficient evidence to begin testing at the nearest contact which fails to operate the circuit properly, although it is well to take the voltage reading between points J and K, Fig. 172, for comparison when making such tests.

566. In some instances, there are controlling contacts in both directions from the location of the controlled instrument and battery. In such cases if none of the controlling contacts operate the circuit, the cause of the failure (that is, unless there are two or more causes) must be between the battery and joints

T and U, Fig. 176, on either side of the circuit, or both in case of a shunt, and can be located by testing as described in Art. 548.

567. If with this arrangement, part of the contacts are still operating the circuit, the method of conducting the test will be governed accordingly, using the principles already outlined.

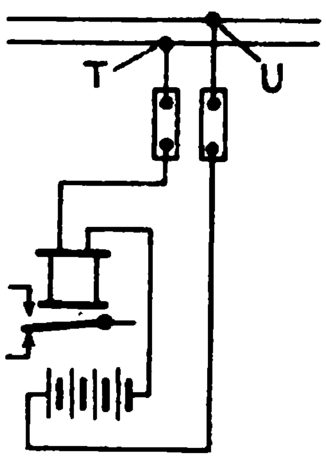

Fig. 176

568. *Batteries at Other Locations.* In some instances, especially when there is but one controlling contact, the battery may be placed at the same location with this contact. In such cases, if the controlled instrument fails to pick up when this contact is closed, it is well to begin testing at the battery location. However, a visual inspection may first be made at the location of the controlled instrument, if convenient.

569. At the battery location, the controlling contact should first be bridged with an ammeter or voltmeter as shown in Fig. 177, in which it is assumed that the circuit is controlled through the back contact of a relay, and if a reading is obtained the contact should now be closed. If this causes the pointer to return to zero, or nearly so, it indicates that the contact and its connections are in good condition; if not, they should be examined and the contact cleaned if necessary.

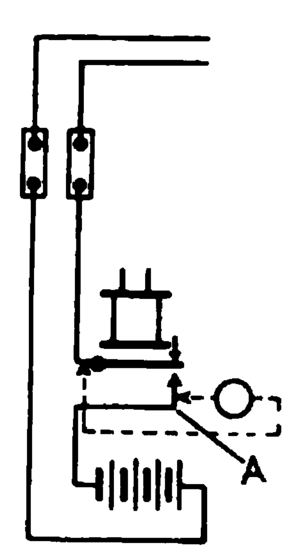

Fig. 177

570. If the meter (in this case an ammeter) gives a reading much higher than normal, it of course shows that there is a shunt on the circuit, between the contact and the controlled instrument.

In case there is such a shunt which is taking considerable current, and the battery is of the open circuit type, it is not desirable to keep it closed onto the circuit very long, as it would be likely to polarize or exhaust the battery. In such instances, if the shunt is found to be outside of the battery location it is the best plan to test for it with a magneto, first at the location of

the controlled instrument and then if necessary on the line, as directed in Arts. 495-496, or if convenient with the Wheatstone bridge, Art. 499.

571. If when the meter was cut in as shown in Fig. 177, no reading was obtained or a low one (below the normal current if an ammeter is employed) and the closing of the contact shows that it is in good condition, the battery should be examined and tested as directed in Arts. 459-461.

572. If the battery is found to be in good condition, a reading obtained on a meter connected in series with the battery, when the controlling contact is open, of course shows that there is poor insulation between the two wires leading from the battery.

573. If a shunt is not indicated by these tests the trouble is probably due to a break or high resistance, and therefore it is advisable to close or bridge, with a jumper, the controlling contact, and definitely determine that such is the case, after which the trouble may be located as would be done in a normally closed circuit, Art. 462, keeping the contact closed (or bridged) until the trouble is located.

574. When testing for failures on circuits which operate vibrating bells or buzzers it is often convenient, when some distance away, to note whether the bell vibrates by observing the motion of the pointer of an ammeter when in series with the bell, or buzzer, although the results obtained vary with the speed of vibration, and to some extent with the type of meter employed. A tester of the type illustrated in *D. C. Track Circuits—Testing,* is also very convenient for making such tests.

575. *Controlled Relay Failing to Release.* If the controlled instrument of a normally open line circuit fails to release properly (or in the case of a bell or buzzer, continues to operate improperly), it is advisable to disconnect the wire from one of its terminals and note the result. If, as in the case of a relay, it still fails to release, it is of course out of order and must be re-

paired or replaced. In other types of instruments some of the parts may have worked out of adjustment.

576. If the instrument releases properly when disconnected, it should again be connected up and its action observed. If it picks up again, or in case it does not pick up and a voltage or current reading taken at its terminals is between its drop-away and pick-up points, it may be assumed that the trouble is not in this instrument. In case there is current still flowing, but not enough to pick-up the instrument (as just mentioned), it is well to leave the meter connected at its terminals and test as follows.

577. Assuming that the battery is at the same location, the wire should now be disconnected at point J, Fig. 172. If this fails to de-energize the instrument or to cause the pointer of the meter at its terminals to go to zero, it shows that there is defective insulation between points J and N, which of course may be more closely located by disconnecting at point L.

If, however, the current is cut off from the instrument when the circuit is opened at J, it should now be closed at that point and disconnected at point K, and if this fails to de-energize the controlled instrument or to drop the meter reading to zero, it indicates that there is defective insulation (probably a ground) between points K and R, which may be located more closely by disconnecting at M.

578. If, however, the current is cut off when the circuit is open at point K, this wire should again be connected, and the test taken up at the location of the nearest contact. At this location, if the contact appears to be in good condition, a meter (preferably an ammeter) should be connected as shown in Fig. 178, in which it is assumed that the controlling instrument is a spring key*.

If a reading is now obtained it shows that there is defective insulation at this location, which can be more closely located by

*See footnote Art. 556.

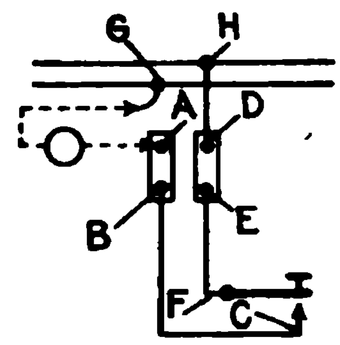

Fig. 178

disconnecting at points B and C. If no reading is obtained, the wire should be replaced at A and a similar test made with the meter cut in at D, disconnecting if necessary at points E and F. If one of the line wires, for instance that connected to point D, is a permanently grounded common wire, the test at that point may be omitted, the testing being confined to the control wire. If this does not locate the trouble, similar tests should now be made at other contact locations, until all have been tested or the trouble found.

579. If these tests are not effectual in locating defective insulation, the rubber covered leads, from the arresters to the line wires at the various locations should be examined or tested.

At the location of the battery and controlled relay, they are tested by observing the action of the relay or a meter in series with it, as mentioned in Art. 577, when the wires are disconnected first at joint T and then joint U, Fig. 172. Another method is to leave the relay properly connected and cut a meter in series, first at one joint and then at the other, in which case a reading indicates that the rubber covered wires are in good condition. If no reading is obtained at one of these joints, it should be left open and the current at the relay noted; if there is still current passing through the relay, it of course shows that the insulation of the disconnected rubber covered wire is defective.

580. To test the rubber covered wires at the locations of controlling contacts, the meter should be cut in first as shown at joint G, Fig. 179, and then at joint H, where a reading, at either point, will show defective insulation on the rubber covered wire connected to it.

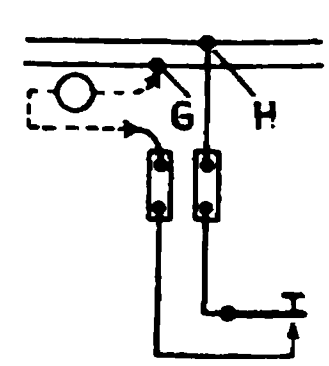

Fig. 179

581. If these tests fail to locate the trouble, it must be on the line where it can be located by cutting the line and testing with the meter or with a magneto, or by the use of a Wheatstone bridge.

In these tests it should be remembered that the cross or ground may be at any point between the extreme ends of the circuit.

If a ground on the control wire is thus located, the removal of which restores the circuit to working condition the corresponding ground, either on the other side of this circuit or, if a common wire is employed, on another circuit, should, of course, also be located and removed, that is, unless the common wire is kept permanently grounded.

582. In case an open circuit battery is employed, which would be likely to become polarized or exhausted if kept closed onto the line for testing, or in case the controlled instrument is a bell or buzzer which would be troublesome if allowed to operate continuously, then, if the trouble is not found at the location of the controlled instrument, it will probably be desirable to disconnect the circuit just outside the lightning arresters at this location (as at points J and K, Fig. 172) and test with a magneto at the contact locations as shown in Fig. 180, in which case a ring will, of course, show trouble at this location.

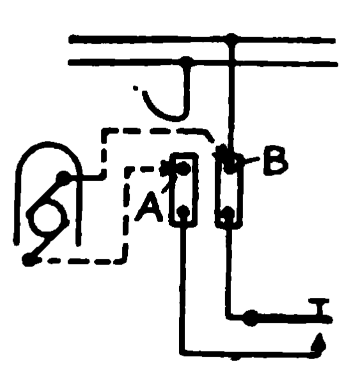

FIG. 180

If no ring is thus obtained the wire ordinarily connected at point A should now be touched to the binding post while the magneto is being operated; this should now cause a ring showing that there is poor insulation on this side of the circuit outside of the arresters. If the other side of the circuit is on a separate wire or on a common which is ordinarily kept free from grounds, the same test should now be made at point B.

583. If there are controlling contacts in both directions from the controlled relay, as in Fig. 176, and if after testing at the location of the battery and controlled relay, it is necessary to go to the controlling contacts, it is well to test the shorter end first, or the end on which there are the fewer contacts.

584. When testing the controlled instrument as described in Art. 576, it may occasionally happen that the armature drops

when it is first disconnected and does not pick up again, or a reading is not obtained on the meter, when it is again connected. In such cases it is well to connect a test wire as shown in Fig. 181, while the meter is still connected, which should, of course, energize the relay and give a reading on the meter. The test wire should now be removed, being careful not to jar the relay. If the armature now stays up and a reading is obtained it shows that there is defective insulation in the relay.

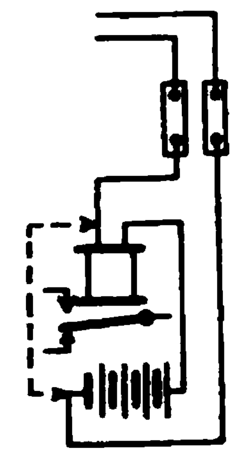

Fig. 181

585. If the battery is at the location of the controlling contact (assuming that there is but one), and if it has been determined that the apparatus at the controlled instrument is in good condition, it is desirable to go to the controlling contact, and if this appears to be in good condition, a meter should be placed in series at the battery.

If the circuit is isolated,* a reading should now be obtained, showing that there is defective insulation between the battery and the contact, which is operating in connection with another defect between the contact and the controlled instrument. It is well now to disconnect as at point A, Fig. 177, which will show whether the defect is in the wire or the instrument.

586. If the wire is grounded it may be disconnected at both ends and a temporary substitute employed, while it is being repaired. The second ground may be located with a magneto, first testing at each end and then if necessary on the line with the rubber covered wires at each end disconnected from it. It will be observed that this is also a very favorable condition for the use of a Wheatstone bridge, as an additional wire is not necessary.

587. If the return for the circuit is on a common wire and no reading is obtained when the meter is cut in at the battery, it indicates that the control wire is grounded, and that current is coming from another circuit, as shown in Fig. 142. In

*Not connected to any other, as by a common wire.

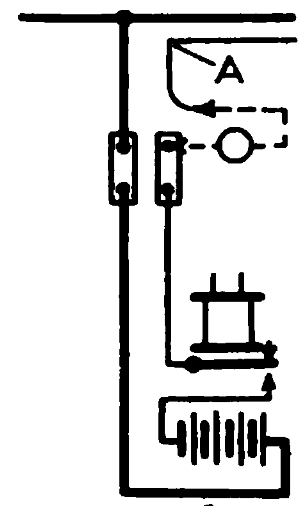

Fig. 182

such a case a meter should be connected as shown in Fig. 182, a reading indicating that the ground is between the meter and the contact, and no reading, that it is towards the controlled instrument. If the latter condition is found, the test should now be repeated at joint A where the rubber covered wire is attached to the line. If this shows that the ground is still further towards the controlled instrument the rubber covered wire at that location should now be tested in a manner similar to that described in Art. 579. If necessary the test should now be made by cutting the line.

This ground may, of course, be located by the use of a magneto or bridge.

588. If, when the battery is not at the location of the controlled instrument, this instrument, after being disconnected, fails to pick up, as described in Art. 584, it is well, if convenient, to test it with a battery of about the same voltage as that used on the circuit, which may often be borrowed from some other circuit temporarily. One terminal of this temporary battery should of course be attached to the common wire and the other used to test with, as described.

589. *Grounds on the Common Wire.* If a common wire, which extends several miles and forms part of a large number of circuits, is found to be grounded, and an inspection of lightning arresters, etc., fails to remove the ground, it may be desirable to cut it in order to locate the ground. In doing this considerable care must be exercised not to produce any of the dangerous conditions described in Arts. 127-134.

590. With this end in view, a location should be selected near the middle of its length, if possible, where only one circuit is using the common wire; then the control wire of this circuit should be opened at the most convenient point, and the common wire then opened and tested for a ground, with a magneto, first in one direction and then in the other.

After the common wire and the control wire are again con-

nected the test should be repeated at a location which will about equally divide the remaining portion of the common where it is possible for the ground to be. If it were found to be grounded each way from the location of the first test, it will, of course, be necessary to conduct two series of tests, one in each direction.

591. When it is not possible to select a location where the common wire acts as a conductor for only one circuit, it is of course necessary to open all control wires which pass the point where the common wire is to be cut. However, by selecting a suitable location at the ends of one or more circuits, as for instance at a highway crossing, it may be possible, by arranging some temporary wiring, to keep most of the circuits in operation while the test is being made. For example, in Fig. 183, the circuit controlled through the contact on relay A is opened at point B, as already explained, while the tap from the common wire is disconnected from relay C, the temporary tap shown dotted first being run from this terminal of the relay to the common wire just west of point X, where the common wire is to be cut. Thus the circuit through the contact of relay A is the only one which is out of service while the test is being made.

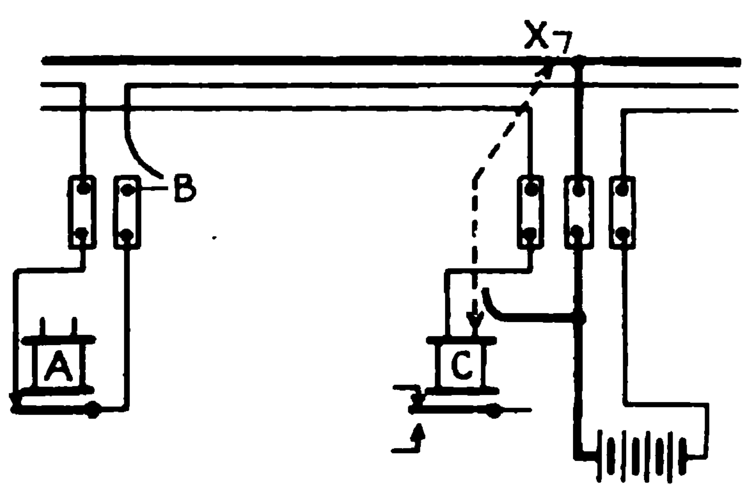

Fig. 183

592. As may be assumed from the foregoing, a common wire may be extended indefinitely carrying current for any number of circuits at various points. However, in order to more readily locate grounds and to limit the effects of foreign current (Art. 594) it is the practice in many cases to limit the common wires, a length of ten miles being considered good practice, although in some instances it has been found desirable to limit them to a length of two miles.

593. Stick Relay Circuits: When testing for failures on normally open stick relay cicuits, it is usually the best plan to disconnect the stick circuit at the relay contact and then to test

as has been described for ordinary normally open circuits. When testing on normally closed stick relay circuits the stick circuit should be closed by a temporary jumper connected around the stick contact, and the test conducted as described for normally closed circuits.

As such alterations in the circuits are likely to cause dangerous conditions, these should be guarded against before the changes are made.

594. Foreign Current: As already intimated, trouble is sometimes experienced on line circuits, by the presence of foreign current.

595. *Source.* As in the case of track circuits, the principal sources of foreign current on line circuits, is leakage from high voltage circuits such as electric car, power and lighting circuits,* stray propulsion current being generally considered the most common.

Leakage through the insulation on wires, especially long common wires having many branches carried underground through damp trunking, often allows enough stray current to collect on these wires to interfere with the operation of instruments connected to them.

596. In some cases a voltage reading may be obtained between the common wire and the ground which varies considerably, often changing in polarity.

In such cases it will be seen that a ground on a control wire might cause a clear failure, and thus a very dangerous condition result

In other cases the foreign voltage may neutralize or reverse the flow of current in a circuit, possibly by overloading the common wire (Arts. 128-134) and thus cause intermittent failures, resulting in the occasional improper ringing of an alarm, etc.

*The term "foreign current" is frequently applied to current which may leak from one signal circuit to another, as shown in Fig. 142, but as generally applied means current from other sources, and unless otherwise noted, will be so understood hereafter.

597. *Testing.* Whenever there are high voltage circuits in the neighborhood of line circuits, especially when a common wire is employed, it is a very good plan to occasionally test with a voltmeter between various parts of the circuits and a ground, the lightning arresters being a convenient point to do this. If a reading is obtained it is advisable to observe for several minutes the action of the voltmeter. When testing on a circuit, a ground on another circuit connected to the same common wire may of course produce a reading, in some cases as high as the sum of the two highest voltage batteries connected to this common wire,* but an exceptionally high voltage at any time indicates foreign current. Readings caused by it when due to propulsion current, will often be found to change in a manner apparently following the movement of the controller on an electric car.

598. *Remedies.*** In circuits employing direct current, probably the most efficient remedy for foreign current is to provide a separate return wire for each circuit, and employ back contact shunts on controlling devices, wherever possible, care being taken that they are so connected that the controlled instrument and not the battery, is shunted by the back contact. These back contacts should frequently be inspected, their resistance tested, and when necessary cleaned, so that they will at all times be effective in shunting out any foreign current which may appear. If a back contact is found to be blackened, it is usually an indication that it has been carrying considerable current, the source of which should if possible be determined, with a view to overcoming it.

599. If it is not practicable to provide a separate return for all circuits, conditions will often be considerably improved by cutting the common wire at as many points in its length as circumstances permit. Of course, where circuits using separate commons overlap, the common wires must also overlap; however, when cutting common wires, points may often be selected where

*See Art. 542.

**It is generally conceded that the best method of guarding against foreign current is the use of *alternating current* of the proper frequency in the signal circuits, with instruments which will respond only to such current.

only a small amount of additional wire will be required on account of overlapping.

600. Frequent tests should be made for grounds, the most suitable time being after a long rain when everything is in a very damp condition. A magneto is very convenient for this purpose, as it may, in most cases, be used at any time without danger of improperly operating any of the apparatus. A close watch should be kept on lightning arresters as they are generally the weakest spot for accidental grounding.

601. In some cases it has proved beneficial to raise buried trunking, through which line circuits pass, and place it upon stakes clear of the ground. This tends to keep the rubber covered wires dryer and thus they are less likely to become grounded.

602. It may be found advantageous to study the situation, taking into consideration the location of the power house or substation of the high tension circuits, from which the trouble seems to come; also the polarity of these circuits and the direction in which they are likely to cause leakage to flow. It may sometimes be possible to note the location of cars on an electric road when the trouble is present. If the route of the foreign current can thus be determined, a path may sometimes be provided for it, possibly by grounding it or otherwise, and then blocking it off from the signal circuits where it formerly reached them.

In some instances the use of higher resistance instruments, which of course require a higher voltage to operate them, may improve conditions.

603. Intermittent Failures: If it is found that a line circuit is subject to intermittent failures, and the maintainer does not arrive on the ground when it is failing, he should make a very thorough inspection of all portions of the circuit which are accessible. All binding posts and connectors should be examined to be sure that there are no loose binding screws or nuts and the wires attached to them tested with a slight pull

as they are sometimes cut off within a post or connector, or broken off close to them.

It is desirable, especially if the controlled relay or other instrument failed to release, to make a test for a ground on the circuit with a magneto as the failure may have been caused as explained in Arts. 530 and 542; or in a similar manner. In some cases failures may be caused by battery wires or connectors becoming grounded onto the inside of iron chutes.

604. The possibility of a break or high resistance in the common wire, or of an overloaded common, should be considered, and also the possibility of foreign current, all of which are likely to produce intermittent failures.

Bare line wires if not pulled up tightly may sometimes swing producing intermittent crosses or grounds.

If it is found that the failures recur at any particular time of day, as for instance such failures as are due to expansion and contraction of metal by change in temperature, it may be desirable to be on the ground at that time so as to test when the trouble is "on".* If by so doing the maintainer can determine whether the trouble is being caused by a break or high resistance, or by a shunt, it will of course be of considerable assistance as a guide in locating it.

605. Circuits in Trunking: Testing for failures of circuits in trunking is usually conducted in a manner similar to that described for line circuits. If it is found necessary to cut into the insulation of wires for testing purposes, this should if possible be done in slack boxes where the cuts may afterwards be easily inspected whenever desired.

The directions given for cutting and repairing the insulation of weather-proof wire (Arts. 476 and 479) should be followed, although in some instances it may be desirable, in order that the resulting insulation be as good as the original, to cut away the braid each way for one or two inches and apply rubber tape and P. & B. compound, before applying the friction tape.

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*Present.

606. Instances have occurred in which the insulation on rubber covered wires which were run in trunking buried in damp ground for a length of only a few feet, had deteriorated so much that with a battery of less than 10 volts, enough current leaked from one wire to another to prevent the controlled instrument from releasing properly. In such cases these wires had evidently been left in service too long, and in order to avoid such conditions, it may be found desirable to occasionally test the insulation between wires in underground trunking with a good magneto (one that will ring through at least 40,000 ohms), or with other suitable testing instruments.

607. Combination of Causes: It will be observed that in the tests given for locating the cause of failures in line and bell circuits, it has been assumed, except in some of the cases of shunts, that there is but *one* cause of failure present at one time. However instances may occur in which the failure is the result of *more* than one defective condition. For example, a line wire may break and one or both ends may lay on the ground, perhaps in water, thus the circuit may be grounded as well as broken. Therefore, if, when testing, the readings obtained are not as expected, they should be judged, having in view various possible combinations of defects.

GENERAL MAINTENANCE

608. Designation: In order to readily identify the location of alarms, in telegrams, etc., they are usually given some designation. This may be the name of the street, as for example, "Columbia St., Colorado Springs", but where the name of the street is not well known, the crossing may have a name such as "Smiths' Crossing, Carlisle". However, where there are two or three alarms close together such designations as "North", "Middle" or "South Crossing, Croton Falls", are frequently used.

609. Another method, which is very convenient on sections where there are a large number of alarms, is to *number* each one, starting at one end of the section or division, and allow-

ing a number for each crossing where it is possible that an alarm may be placed. Thus if a new alarm is installed, it will simply take the number provided for it, and consequently all alarms will be numbered in consecutive order. These numbers are usually painted on a white board in black figures 4 or 5 in. high, the board being mounted in a suitable place on the bell post.

By using numbers in this manner, much confusion resulting from streets of the same name in different villages, etc., may be avoided.

610. Daily Tests and Reports: As already mentioned it is very desirable to have all alarms tested daily. Any crossings that are within reach of the maintainer or a competent helper may be tested by them, but, in many cases the crossings are out of their reach and some other employe must be detailed for this duty, the track patrolman or a station attendant often being employed.

611. The best test that can ordinarily be made in such cases is to be present at the crossing when a train is approaching and observe the operation of the alarm, noting that it *starts* and *stops* when the train is at the proper point, and that the bell gives a loud, clear ring. This observation should, of course, be made separately for movements on all tracks over which it is customary for trains to pass, and for each direction in single track arrangements. As it is not always practicable however to make such a test, the use of test keys, etc., may be satisfactory, except as noted at various points in the explanation of the circuit arrangements.

612. Only such persons as are familiar with the operation of the alarms in relation to train movements should be permitted to test them. This is especially important in the case of test keys as improper testing may result in delays to trains or inconvenience to traffic on the highway.

613. In some instances it is customary to require those who test alarms to fill out a daily report and forward it by train

mail to the Supervisor of Signals or to the Division Superintendent, in order to insure that the test has been made. A reduced fac-simile of such a report form is given below, which is intended for use where switches are employed instead of keys for testing.

S. P. & N. A. R.R.

SIGNAL DEPARTMENT.

...................*190*..

To......................

Title....................

at....................

I hereby certify that I personally examined and tested Signal Bell No.......................

located.......................

....

at the hour of.................

190..*and found it in the following condition*.................

....

....

Signed.....................

Title..................

(See Instructions Other Side.)

(FRONT)

INSTRUCTIONS.

The person who is designated to look after signal bells, must make a test of each bell each morning as early as possible, and know they are in working order. If out of order he must arrange to protect the place until the defective condition is reported and repaired. One of these forms must be filled out at each inspection and sent to the officer designated to receive it.

Bells are to be tested by unlocking the box on bell post that is provided with a switch lock and closing, one at a time, each knife switch found in box. If bell rings each time a switch is closed, bell is in working order. Switches must always be left open, whether bell is in working order or not.

(BACK)

614. Hand Car Insulation:* In order to avoid false operation of alarms, it is customary to so insulate hand cars, that they will not shunt track circuits. Another effect which may

*This of course, applies to all forms of light cars.

be produced by uninsulated hand cars, is the locking of an interlocking relay when a train is approaching, thus interfering with the proper operation of the alarm.

Hand cars are frequently insulated at the factory, such insulation usually being most satisfactory. However, where cars, that are not insulated, are in use, the necessary insulating parts may be applied with good results.

The insulation should occasionally be tested with a magneto, blocking up one side of the car to prevent the current from passing through the ground.

615. Temporary Flagman: In some cases, in order to avoid false ringing, it is desirable to cut out an alarm and station a temporary flagman at a crossing when a controlling track circuit is to be occupied by a train for an unusually long time. In such instances, the alarm should be tested when again cut in.

616. When a temporary flagman is stationed at a crossing on account of the failure of an alarm, his instructions should be such that he will remain there *after* the maintainer arrives, until released by the latter. If the flagman should leave upon the arrival of the maintainer and the alarm could not be put in operation without the maintainer having to leave the crossing, he would either have to leave it unguarded, or be delayed in making repairs.

617. In some instances it is customary to have a sign, ordinarily kept in a suitable receptacle at the bell post, which may be attached in a conspicuous position on the post, to be observed from the highway. This sign is lettered "DANGER, Bell out of Order" and is placed on the post by the person who makes the daily test, if he finds that the alarm is not working properly. When so posted, it should be removed only by the maintainer, when the alarm is again in working order.

618. Reporting Failures to the Maintainer: Reports of failure should be forwarded to the maintainer by wire, as soon as possible, giving as much information as may consistently be contained in a telegram. For instance, rather than saying

"Bell 38, out of order", the trouble should if possible be stated more fully, as "Bell 38 ringing continuously", or "Bell 38 fails to ring for west-bound trains". By receiving such information the maintainer may often be able to judge what is the cause of failure and govern his method of procedure accordingly.

619. **Maintainer's Inspections:** It is advisable to make a general inspection periodically of all parts of the apparatus. In cases where the maintainer takes care of the batteries, this can usually be done at the time of the regular visits to the battery; otherwise, visits not more than one month apart should be made for this purpose. On such visits each part of the apparatus should be inspected as has already been described, adjustments noted, wear taken up and bearings lubricated if necessary. It should, of course, also be observed that all binding screws and nuts are tight.

620. It is very desirable that the maintainer become as familiar as possible with all his circuits when in their normal condition, keeping a record of the voltage of each battery and at various other points in the circuits as convenience permits, also of the normal current flowing in each circuit,* voltage drop at contacts, etc. By checking these readings occasionally during inspections, slight defects may frequently be discovered and remedied before they become serious enough to cause failures.

621. When riding on trains, it is often possible as mentioned in Art. 287, for the maintainer to observe part of the operation of an alarm; that is, he can usually hear it ring as the train passes and sometimes observe that it stops properly. By following this practice it is frequently possible, especially after thunder storms, to discover failures and make repairs, before the regular daily test is made, thus shortening the length of time that that alarm is out of service and in some instances preventing a battery from becoming polarized or exhausted.

If an alarm is found to be out of order and the crossing not

*It will be remembered that a knowledge of the normal readings is required in many of the tests given.

guarded, the maintainer may be able to guard the crossing while making repairs (Art. 515), but if he finds that he will have to leave the crossing in order to remedy the trouble, he should take steps to have it guarded. If convenient he should, of course, arrange to have a temporary flagman furnished from the usual source, but in some cases it may be more expeditious to detail a helper to guard the crossing, especially if conditions indicate that repairs will be completed in a short time.

622. Locating Causes of Failure: The first thing to be ascertained when proceeding to remedy a failure, is which *circuit* is out of order.

In some cases one failure will lead to another; for instance, when open circuit cells are employed in a bell battery, the failure of a track or line circuit may result in the bell ringing continuously until the bell battery becomes polarized or exhausted. A shunt on a normally open circuit may produce a similar effect on its battery. In such cases the repairing of the battery and the remedying of the original cause of failure should if possible be conducted together in order to put the alarm in operation as soon as possible.

Other combinations of the causes of failure which have been described, may be present, and especially if of an intermittent character, may be found somewhat difficult to locate. However, if the maintainer is familiar with his circuits and has at hand a record of the normal readings, he should, by comparing these readings with readings now obtained and by observing the operation of the apparatus, be able to judge the nature of the defects and their probable location.

623. On account of the great variety of circuit arrangments in common use, it will occasionally be found desirable to employ modifications of the tests described or in some instances to conduct them in a different *order* from that given. For example, if the report of a failure received, indicates that a certain relay had failed to pick up, and it is known that the battery for this circuit has recently been renewed or repaired, it would probably be advisable to inspect the battery first, es-

pecially if more convenient to reach than the relay, as it is quite likely that a jar was cracked and put back in service unnoticed.

624. After a circuit has been disconnected or after the cause of failure of a circuit has been remedied its operation should be tested, before leaving it. The best method, of course, is to observe its action in regular service, but if no train is likely to pass within a reasonable length of time, the operation of a line circuit, for instance, can often be tested by shunting a controlling track circuit. In any case the test should be as near a duplicate of the regular operation of the circuit as circumstances will permit.

625. Maintainers' Failure Reports: It is customary to have the maintainer, after locating the cause of failure, and repairing it, note on the report which he has received, the *time* that he *received* it, the *time* when he *arrived* at the defective alarm, the *cause of failure*, the measures taken to *remedy* the failure, and the *time* when repairs were completed, and to forward it to his superior. In some instances a blank form is provided for this purpose.

EXAMINATION QUESTIONS

(1) Why is it undesirable to provide fouling sections with track circuits that only operate crossing alarms?

(2) If it is desired to give 40 sec. warning of the approach of a train to a crossing, how far would the track circuits extend from the crossing assuming the maximum speed of trains to be 40 mi. per hour?

(3) After wiring is installed, what tests of same is it desirable to make?

(4) What rules should be observed when wiring in insured buildings?

(5) What effect would probably be produced by using a battery whose voltage is considerably higher than required by the instruments it operates?

(6) Why should knife switches, which are used with high voltage apparatus, be opened with a quick motion?

(7) What condition is indicated if, in Fig. 138, a voltmeter gives different readings when bridged first from post B to spring E and then to armature F?

(8) What condition is indicated in Fig. 138, assuming that the bell will not operate with the normal voltage at its terminals, if a jumper connected from post B to armature hanger G, causes it to operate?

(9) If a magneto when operated, fails to ring with its terminals connected to binding post A, Fig. 138, and contact post D, what condition is indicated?

(10) What portion of a bell is most likely to cause trouble?

(11) Why are lightning arresters more generally used on line circuits than on track circuits?

(12) How would it be possible for a circuit to become permanently grounded at a saw-tooth lightning arrester?

(13) Assuming that there is no other trouble on a circuit, how many grounds are necessary to produce a failure when the common wire is not permanently grounded?

(14) If two wires extending to an instrument are disconnected from all apparatus (that is, so that each wire is isolated) and a magneto whose terminals are connected one to each of these wires, rings when operated, what causes may produce such an effect?

(15) What apparatus is the most likely to become grounded?

(16) If a wire of a bell circuit is found to be broken what means are generally employed to place the bell in operation, before this wire is repaired?

(17) During what weather conditions is it advisable to test for grounds?

(18) Why should cut-out switches be mounted with their handles down when closed?

(19) If the readings of a voltmeter connected between a common wire (not permanently grounded) and the ground vary considerably, what may produce such an effect?

(20) Why is it the general practice to insulate hand cars?

(21) How often should general inspections of apparatus be made?

(22) Why should a record be kept of the normal readings obtained at various points in the circuits?

(23) If the normal voltage at the terminals of a relay fails to cause it to pick up its armature, is the trouble in the circuit or in the relay?

(24) What would constitute a clear failure of a normally closed circuit?

(25) What dangerous condition may be caused by a cross in the line wires between locations A and B, Fig. 160?

(26) Assuming caustic soda cells to be used with the arrangement shown in Fig. 160, what effect would a cross in the line wires between locations B and C, have on the battery?

(27) If in Fig. 171, instead of the circuit becoming grounded at point D, it becomes grounded at point E, as for instance, by a battery connector coming in contact with the side of an iron battery chute, would a dangerous condition exist?

(28) If the relay in sketch A, Fig. 158, operates improperly when its circuit is opened outside of the lightning arresters and with the wire disconnected at points A and F, a temporary jumper connected in its place causes it to operate properly, what may be assumed to be the cause of the trouble?

(29) Which cells, Fig. 135, are still furnishing current to the circuit when the battery is working through jumper A only?

(30) (*a*) If an ammeter in series with tbe bell, Fig. 138, shows a reading higher than normal, and the bell fails to ring, what condition is indicated? (*b*) If the meter still shows a reading when the wire leading to the coil is disconnected from post A, what condition is indicated?

(31) If, when a wire is found to be grounded and causing trouble, it is desired to employ a temporary jumper in its place, why cannot the permanent wire be left connected at any point?

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